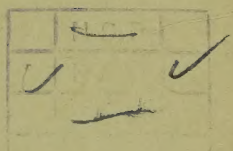
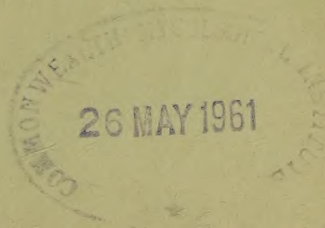
ANNUAL REPORT

of the

WEST AFRICAN COCOA RESEARCH INSTITUTE

1959-60





West African Cocoa Research Institute
Annual Report 1959-60

Errata

Planococcoides gen n. for *Pseudococcus njalensis* Laing.

Reference

Ezzat, Y.M. & McConnel, H.S. (1956). A classification of the mealybug tribe Planococcini (Coccoidea – Homoptera) Bull. Md agric. Exp. Sta., No. A84 3–108.

Page 47. Last paragraph second sentence.
'Table 18, shows however' should read 'Table 17 shows however'.

Page 48. Last paragraph under Table 19.
'Unlike Amelonado cocoa there is little difference in distribution with spraying' should read 'in distribution with spacing'.

Page 49. Shade Efficiency Trial. Second sentence.
'sample weight of weeds will be recorded to assess the efficiency of the different light regimes' should read 'different shade regimes'.

Page 46. POD FUMIGATION (K.B. Armstrong).
'Phytophthora *infestans*' should read 'Phytophthora *palmivora*'.

Page 80. Last line of first paragraph.
'Annual Report *1959-60*, has' should read 'Annual Report *1958-59*, has'.

A Gall Disease of Cocoa

Primary Gall developing from cotyledon axillary bud (*see p. 32*)

ANNUAL REPORT

of the

WEST AFRICAN COCOA RESEARCH INSTITUTE

1959-60

Price 5/-

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1961

A POISONOUS INSECTICIDAL SOLUTION
HAS BEEN USED IN BINDING THIS BOOK

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MANAGING COMMITTEE

At 31st March 1960

CHAIRMAN

*Acting Administrator, West African Research Office.

MEMBERS

*†Director, West African Cocoa Research Institute.
Chairman, Ghana Cocoa Marketing Board.
Mr Osei Bonsu, Ghana.
Mr Y. Sefa-Boakye, Ghana.
*Permanent Secretary, Ministry of Food and Agriculture, Ghana.
*†Chief Cocoa Officer, Division of Agriculture, Ghana.
Permanent Secretary, Ministry of Economic Development, Federation of Nigeria.
†Director of Agricultural Research, Federation of Nigeria.
Permanent Secretary, Ministry of Agriculture and Natural Resources, Western Region of Nigeria.
†Chief Agricultural Research Officer, Western Region, Nigeria.
Rev. E. T. Latunde, O.B.E., Nigeria.
†Director of Agriculture, Sierra Leone.

CO-OPTED MEMBERS (non-voting)

†Director of Agriculture, Eastern Region, Nigeria.
†Director of Agriculture, Southern Cameroons.
Manager, Messrs Cadbury & Fry, Ghana.
Manager, Messrs Rowntree-Fry-Cadbury, Nigeria.
†Deputy Director (Nigeria), WACRI Station, Ibadan, Nigeria.
Secretary, West African Cocoa Research Institute.

* Members of General Purposes Sub-Committee
† Members of Technical Sub-Committee

SENIOR STAFF

At 31st March 1960

TAFO STATION

DIRECTOR	J. Lamb, O.B.E., M.SC., F.R.I.C., A.I.C.T.A.
SECRETARY	H. L. Pugh, A.C.C.S.
ACCOUNTANT	J. N. A. Hyde, A.C.C.S., A.A.I.A.
OFFICE ASSISTANT/LIBRARIAN	Miss D. J. Ellis
ENTOMOLOGISTS	*E. Dunn, B.SC.
	M. R. Smith, PH.D., D.I.C., F.R.E.S.
	K. B. Armstrong, M.A., DIP.AG.SCI., D.I.C.
PLANT PATHOLOGISTS	J. W. Blencowe, PH.D.
	A. L. Wharton, B.SC., DIP.AG.SCI., D.T.A., M.I.BIOL.
	A. A. F. Brunt, B.SC.
	P. D. Turner, B.SC., M.I.BIOL.
	A. Attufuah, M.I.BIOL.
PLANT PHYSIOLOGISTS	R. G. Hurd, PH.D., M.I.BIOL.
	R. G. Lockard, PH.D., M.SC., B.S.A.
PLANT BREEDER	D. R. Glendinning, B.SC.
CHEMISTS	†R. H. Kenten, B.SC., A.R.I.C.
	R. K. Cunningham, B.SC.
AGRONOMISTS	T. H. R. Hall, B.SC. (FOR.)
	R. W. Smith, B.SC.
STATISTICIAN	C. de Jonge, L.I. (WAG.), A.R.N.S.A.S.
LABORATORY TECHNICIANS	
(Electronics)	†A. J. H. Arnold, A.S.E.
(Spectrography)	J. C. Burridge, M.A., B.SC.
MEDICAL OFFICER	P. K. K. Knudsen, CAND. MED. ET. CHIR., D.T.M. & H.
PLANTATION MANAGER	H. W. S. Allison
GUIDE-DEMONSTRATOR	F. E. Decker
MAINTENANCE ENGINEER	G. O. Hayward, ASSOC.I.E.E.
WORKS SUPERINTENDENT	E. K. Berko

* Seconded from East of Scotland School of Agriculture—Edinburgh
† Seconded from Rothamsted Experimental Station

IBADAN STATION

DEPUTY DIRECTOR	T. W. Tinsley, B.SC., PH.D., M.I.BIOL.
ENTOMOLOGISTS	R. G. Donald, B.SC., A.I.C.T.A.
	C. K. H. Martini, PH.D.
	P. F. Entwistle, B.SC., A.R.C.S., F.R.E.S.
PLANT PATHOLOGISTS	J. M. Thresh, B.SC., A.R.C.S.
	D. Kay, B.SC., M.I.BIOL.
	‡E. C. Hislop, B.SC., D.P.P.
CHEMIST	‡P. O. Park, B.SC., A.R.I.C.
AGRONOMIST	J. F. Longworth, M.SC.

‡ Seconded from Colonial Pesticides Research Unit, Arusha, Tanganyika

ADMINISTRATION

Managing Committee

Two meetings of the Managing Committee were held during the year:

28th Meeting was held on 8th and 9th January 1960 at Tafo.

29th (Special) Meeting was held on 3rd February 1960 at Ibadan.

The 28th Meeting gave considerations to the report and recommendations of the Gass Committee on the establishment and functions of the Maintenance Division. An *ad hoc* Sub-Committee was appointed to assist the Director in carrying out the extensive programme of re-organization and reconstruction recommended. A second *ad hoc* Sub-Committee was appointed to examine the structure of the Junior Staff Establishment and to make recommendations to the Committee for the improvement of promotion prospects for Junior Staff.

The 29th (Special) Meeting was called for the purpose of discussing proposals for the expansion of the Ibadan Station and also to consider the draft estimates for Tafo and Ibadan for 1960–61.

Finance

The Chief Accountant proceeded on leave prior to termination of contract in December 1959, and his duties were taken over by the former Assistant Accountant, the post being re-designated Accountant.

The Balance Sheet as at 31st March 1960 is shown at the end of the report.

Staff

Mr J. Lamb went on a special visit to the United Kingdom in August/September 1959, for a period of five weeks, for consultations with the Cocoa, Chocolate and Confectionery Alliance. During his absence Mr E. Dunn acted as Director. Mr Lamb went on leave on 23rd March 1960 and Dr J. W. Blencowe took over as Acting Director.

Dr C. G. Johnson proceeded on leave prior to termination of secondment on 22nd April 1959.

Mr A. Maddison, Maintenance Engineer left on 8th April 1959. Mr G. O. Hayward, the new Maintenance Engineer, joined the staff on 24th May 1959.

Mr G. A. Jones left in June 1959, and subsequently resigned from the service of the Institute.

Mr P. F. Entwistle proceeded on leave in June 1959 and, on his

return in January 1960, was transferred from Tafo to the Ibadan Station.

Dr T. W. Tinsley was on leave until 22nd September 1959 and Mr J. M. Thresh until 8th July 1959. Mr P. O. Park of W.A.F.R.U. was on leave from 23rd April to 19th October 1959, Mr J. F. Longworth from 11th August 1959 to 9th January 1960 and Mr R. G. Donald from 19th December 1959.

Mr E. C. Hislop, Mycologist, formerly of W.A.F.R.U., joined the staff at Ibadan on 26th May 1959 and returned from leave on 10th June.

Mr W. Rides joined the staff on 1st July 1959 as Plantation Officer at Ibadan.

Mr A. Attafuah proceeded to the United Kingdom in September 1959, on scholarship to Reading University.

Mr S. E. N. Kwafo, Station Manager, left on 2nd October 1959 to take up an appointment under the United Ghana Farmers' Council.

Dr M. R. Smith went on leave on 2nd December 1959.

Leave during the year was taken as follows:
Mr H. W. S. Allison, 29th July to 29th November 1959; Mr R. W. Smith, 10th June to 27th October 1959; Mr A. J. Arnold, 8th April to 25th August 1959; Mr J. C. Burridge, 24th May to 5th October 1959; Mr F. E. Decker, 7th September to 29th September 1959; Mr J. N. A. Hyde, 29th April to 17th May 1959; Mr C. de Jonge, 17th July 1959 to 3rd September 1959; Mr R. H. Kenten, 1st May to 26th August 1959; Dr P. K. K. Knudsen, 23rd August to 4th November 1959; Mr E. K. Berko, 21st September 1959 to 16th February 1960.

Mr H. L. Pugh returned from leave on 7th July 1959.

Visits by Staff

Dr Tinsley visited the Belgian Congo in September and October 1959. Dr Martini spent two weeks at Rothamsted Experimental Station in March 1960. Several members of staff visited the cocoa growing areas in the Cameroons, and the Northern and Eastern Regions of Nigeria.

Dr Tinsley and Dr Blencowe attended the 9th International Botanical Congress at Montreal in August 1959.

Dr Tinsley visited Washington, Miami and Costa Rica at the invitation of the American Cocoa Research Institute.

Visitors

The station at Tafo was honoured by a visit from H.R.H. the Duke of Edinburgh on 28th November 1959. Other distinguished visitors included H.E. the Governor-General of the Federation of Nigeria, and Lady Robertson, directors of large-scale commercial concerns interested in cocoa, foreign ambassadors and other public figures.

Visitors to the Ibadan Station included His Excellency the Governor-General of the Federation of Nigeria and Lady Robertson, the Hon. Shehu Shagari, Federal Minister of Economic Development, Lord and Lady Perth, and the Chairman and Members of the Western Region Marketing Board, as well as representatives of the Chocolate Manufacturing Industry in America and the United Kingdom, agriculturists and other scientists from Europe and Africa.

Station and Plantation Management

Ploughing, harrowing, levelling and re-grassing of the Residential Area continued, together with the planting of ornamental shrubs and trees.

Site clearing for the new Central Stores and Botany Division Greenhouse was also commenced.

The planting of two varieties of Amazon cocoa together with temporary and permanent shade on the 35 acres of clear felled land to be utilized as a long term shade and fertilizer experiment (ref. pages 12 and 52 of the 1958-59 Annual Report) was completed at a cost of £28 per acre. Clear felling was commenced in Block C (40 acres), Block E (5 acres) on the Square Mile and 5 acres at Mpraeso.

Recorded data were obtained from 410 tray and 723 heap fermentations.

Forest Tree and Ornamental Nursery

The Forest Tree and Ornamental Nursery was taken over by the Agronomy Division in November. *Fagora melanochoides* ex Belgian Congo and sour and sweet orange seedlings for stocks were planted. Seventy-five thousand seeds of *Terminalia ivorensis* were sown for the 1961 planting programme.

Seed and Cutting Production

A total number of 100,957 F3 Upper Amazon pods were sent to Nigeria and 1,683 to the University College of Ghana for their experimental farm at Kade. 12,168 pods were sold to W.A.C.R.I. employees.

Cuttings were produced for use in the Institute while a small quantity of cuttings was supplied to the Kumasi College of Technology for Experimental purposes.

Cocoa Production

A total weight of 189,976 lb. dry cocoa was produced and 182,840 lb. sold for £G9,550.

Plots Committee

In July, a Plots Committee consisting of three representatives of the scientific staff and Plantation Manager and with the Director in the chair was convened. The function of this committee is to allocate the Institute's land for field experiments.

Experiments submitted by the Agronomy, Entomology and Botany Divisions were reviewed while an experiment to investigate shade and fertilizer as limiting factors in the growth of Hybrids was suggested and approved for submission to the Technical Sub-Committee. It was also agreed that the harvesting year should run

TABLE 1

Meteorological Data—Tafo 1959. Figures for 1959 compared with 22 year means

		Jan.	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*
Highest Shade Maximum	22-year mean	91.5	93.9	93.2	93.8	92.2	89.0	86.9	86.7	88.0	89.8	90.5	90.6
	1959	92	96	96	93	91	89	86	87	89	90	91	89
Lowest Shade Minimum	22-year mean	59.3	62.0	66.2	66.8	67.0	66.3	65.9	65.1	67.1	66.9	65.9	62.7
	1959	61	61	67	69	67	69	70	66	69	68	68	62
Mean Relative Humidity (09.00 GMT)	22-year mean	86.3	83.9	82.1	81.0	81.9	85.1	86.1	85.9	85.4	83.4	81.4	84.3
	1959	84.2	83.1	82.4	82.8	84.1	85.0	88.5	85.6	85.5	82.5	82.1	85.8
Mean Relative Humidity (15.00 GMT)	22-year mean	55.9	53.4	57.1	60.1	64.9	70.6	70.9	69.4	71.3	72.4	66.1	61.9
	1959	56.0	53.9	60.3	66.2	71.2	76.0	78.4	69.4	71.8	71.2	69.4	64.5
Rainfall in inches	22-year mean	1.49	3.52	6.07	6.09	7.65	8.57	5.75	2.42	5.92	8.73	40.2	2.44
	1959	0.29	2.08	9.84	6.68	9.36	7.72	10.83	1.90	6.11	7.55	2.98	2.79
Number of Wet Days	22-year mean	3.7	6.8	11.9	11.2	14.1	18.9	14.0	12.5	14.5	18.9	11.2	6.3
	1959	2	5	13	13	15	18	21	7	14	22	12	7

Annual Rainfall (in inches) 1938 to 1959

1938–47 *Mean*	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	*22-Year Mean*
57.87	66.99	71.81	63.47	66.23	65.77	53.88	57.53	73.16	51.12	70.90	61.86	68.13	62.98

Monthly Rainfall (in inches) and Number of Wet Days, April 1959 to March 1960

Month	*April*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Jan.*	*Feb.*	*March*
Rainfall in inches	6.68	9.36	7.72	10.83	1.90	6.11	7.55	2.98	2.79	2.95	3.28	6.84
Number of Wet Days	13	15	18	21	7	14	22	12	7	4	8	16

from the 1st March to the 28th/29th February of each year instead of from the 1st April to the 31st March as hitherto.

The value of the Old Station was reviewed. It was made clear from the summarized records, that data is being obtained at considerable expense and that no justification for the continuation of yield recording could be given. It was therefore agreed that the recording in the Old Station should be discontinued except for selected high yielding plots.

Ibadan Station Development

Experimental Station at Gambari

The Northern portion of the Gambari Forest Reserve was chosen from various other sites within the Ibadan Area as the most suitable for the establishment of an experimental station. In collaboration with the Forestry Division of the Ministry of Agriculture and Natural Resources three blocks of land (North, South and West) containing good cocoa soils were selected. The whole comprised some 700 acres of which approximately 350 acres are suitable for cocoa cultivation.

The boundaries of all blocks have been demarcated and beacons placed at changes of direction, with intermediate pillars at 20-chain intervals. Where possible forest compartment boundaries were used. Pending finalization of a lease, the boundary traces are being kept open and only preliminary clearing is being done.

Water Supply

There is a major problem of providing an adequate water supply for domestic and laboratory use. Three possible sources have been investigated:

(*a*) The sinking of wells.
(*b*) The construction of a storage dam across a temporary stream.
(*c*) To draw water from the River Ona.

Sources (*a*) and (*b*) have proved to be unsuitable. The River Ona forms the Western boundary of the plantation and analyses of water samples show heavy contamination with faecal *B. coli*. Expert advice has been obtained and two firms of high repute have given assurances that adequate filtration would produce a potable supply. Proposals and estimates for a water treatment plant are being examined.

Building Sites, etc.

Selected sites for senior staff quarters and labour lines have been cleared of low bush and approved by the architects. The Electricity

TAFO STATION

EXPERIMENTAL AREAS

TRIALS ON PLANTED COCOA

Agronomic Investigations

A3–Clonal collection.

B1–Upper Amazon multiplication area.

B2–Upper Amazon spacing and pruning trial.

C2–Amazon thinning trial.

C4–Varietal Shade and Manurial trial.

D7–Pruning trial.

G1–Rates of Major Nutrients

G4–Amelonado source trial.

H1–Second establishment trial.

H4(a)–Pilot Irrigation trial.

H5–Cover Crop and Mulches.

J1–Amelonado spacing trial.

J3–Clonal cocoa management observation.

L2–Second establishment trial—Amazon extension.

P2–Amelonado pruning trial.

SG–(Old Station) seed garden.

H4–Hybrids planting.

Botanical and Plant breeding investigations

A5–Seedling growth experiment.

D5–9th P.T.A.

D8–Clonal Trial III (Pod disease resistance studies).

D9–9th P.T.A. progenies.

I1–Seedling growth experiment.

M2–1st Clonal Trial (Ghana selections).

N1–Trinidad introduction area.

N2–Species area.

N3–Trinidad introduction extension.

N4–2nd Clonal Trial (Pod disease resistance studies).

N5–Multiplication area.

N6–Observation area including Polyploid plot.

N7–8th P.T.A.

N7(a)–2nd Albino plot.

N8–Columbian introductions.

N9–F1, F2 and F3 trial.

N10–W.A. E5 plot (1958).

N11, N12, N13 – Small experiments established 1959.

N14–Mass planting of varieties.

P1–Early bearing experiment.

P9–Variety progeny comparison trial.

P.T.A. (Old Station) 1st and 2nd Progeny Trial areas.

Pathology investigation

A2–Collection of material showing tolerance to swollen shoot virus.

A4, H2, H3 – Cause of mortality experiments.

E1–Swollen shoot virus resistance variety trial, 1959, 1960.

2nd P.T.A. Pod disease resistance studies.

Soil science chemistry investigations

A6–Amazon establishment on clear felled land.

G1–Fertilizer trial rates of N.P.K. Mg.

G5–Fertilizer trial.
2^4 N.P.K. Mg. factorial.

I2 – An establishment on exposed village site.

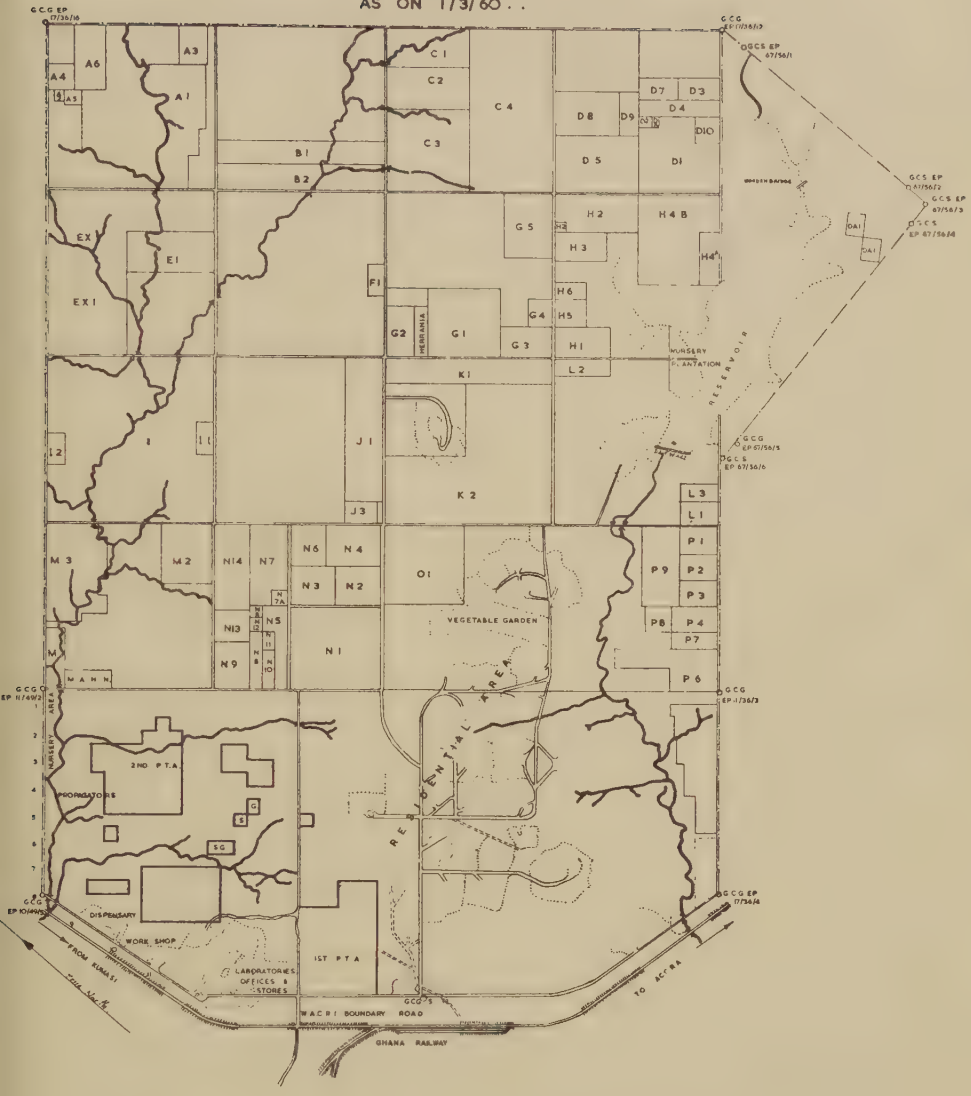
K1–Amelonado Shade and Fertilizer trial.

O1, K2 – Amazon Shade and Fertilizer trial.

Entomological investigation

H4(b)–Ecological insect studies.

FIELD INVESTIGATIONS
AT
W.A.C.R.I.
AS ON 1/3/60..



SCALE 1:5000
OR 5 INCHES TO 200 FEET

FEET 200 0 200 400 600 800 1000 1200 1400 1600 1800 2000 2200 FT.

Corporation of Nigeria are investigating the possibility of supplying power. Permits for the installation of private generating plant require the approval of Electricity Corporation of Nigeria and their decision is awaited. It is proposed to run all plantation transport on Diesel power, and the first purchases have been a Land Rover and one Massey Ferguson tractor.

Site for a New House at Moor Plantation

The Government of the Western Region have agreed to arrange a 99-year lease of a building site on Moor Plantation on which the Institute will build a new house made necessary by the addition of a Secretary to the establishment of the Institute.

VIRUS RESEARCH

MECHANICAL TRANSMISSION OF COCOA SWOLLEN SHOOT AND MOTTLE LEAF VIRUSES (A. A. Brunt and R. H. Kenten)

Infective slurries have been prepared from seedlings of *Adansonia digitata* L. infected with cocoa swollen shoot or mottle leaf virus by vacuum-infiltration of detached leaves and cotyledons with a cold solution (4–10°C. pH 8 or 8.5) containing phosphate, cysteine, and usually ethylene-diamine tetraacetate. Infectivity was demonstrated by applying such slurries to the embryo and inner surface of cocoa half-beans with a brush or forefinger. Transmissions occurred in about half the experiments; the best rates of transmission were 13.5 per cent. with swollen shoot virus and 4 per cent. with cocoa mottle leaf virus. Symptoms usually appeared on the second flush of leaves 6–7 weeks after mechanical inoculation of the beans, but occasionally after three weeks on the first flush.

No infection occurred in control experiments in which slurries from healthy leaves infiltrated in the same way were used as inocula. Over the period of the experiments all the untreated half-beans which were sown and grown alongside the inoculated beans remained healthy.

Using the same method, attempts to transmit swollen shoot virus from infected to healthy *A. digitata* seedlings failed. However, transmissions were obtained with inocula made by centrifuging the slurries for 5 minutes at 8,000 *g.* and concentrating the supernatant solution by dialysis against sucrose solution (50 *g.* sucrose per 100 ml. solution) for 2–3 hours and also after concentration of the clarified extract by ultrafiltration. The average rate of transmission was 19 per cent.

Infiltration of cocoa leaves proved more difficult, and was still incomplete after repeated exposure to vacuum. Slurries made from this material were non-effective.

THE EFFECT OF VIRUSES ON GROWTH AND YIELD OF COCOA (J. W. Blencowe and A. A. Brunt)

In experiment A4 (*Rep. W. Afr. Cocoa Res. Inst.*, 1958–59, p. 19), in which the effect of 5 viruses on the growth and yield of young Amelonado cocoa is being compared, a few trees infected with each virus showed symptoms four months after graft-infection. One year after inoculation, swellings have been found on 45 per cent. of trees infected with the Worawora isolate whilst between 85 and 95 per cent. of the trees inoculated with the more severe isolates from Bosomuoso, New Juaben, Dawa and Kpeve have produced swellings and/or leaf symptoms.

In experiment H2/3, designed to study the effect of infection with a severe swollen shoot virus on trees grown in the presence and absence of a compound fertilizer and with and without shade only 46 per cent. of Amazon trees showed symptoms one year after graft-infection. By contrast, 80 per cent. of similarly graft-infected Amelonado trees became visibly infected during the same period.

All plots of both experiments received applications of *gamma*-B.H.C. in June, July, November and December at the rate of 2 oz. insecticide per acre. Although no recent capsid damage has been detected in these experimental areas, the canopy of many trees infected with severe virus isolates in experiment A4 began to deteriorate nine months after infection; such plots gave the appearance of small swollen shoot outbreaks. Infection with the severe New Juaben isolate has so far had little effect on the canopy of infected Amazon trees in experiment H2/3 but, as in experiment A4, that of Amelonado trees has been severely affected.

Girth measurements, canopy assessments and yield records collected during the past year have been summarized for comparison with similar data to be collected in subsequent years.

All the projected experiments (*Rep. W. Afr. Cocoa Res. Inst.*, 1958–59, p. 19) being made in collaboration with the Division of Agriculture to determine the effect of capsid-spraying on the subsequent growth of virus-infected trees have commenced. Twenty-seven units (each unit comprises one treated and one untreated plot) have been established. Of the 24 units in the Eastern Region, 10 have been sited in an area affected by a severe swollen shoot virus, 11 in an area where a relatively mild virus is prevalent and 3 in an area where there are mixed infections with a severe and a moderately severe virus. The remaining 3 units are in the Western Region where there is much capsid damage on the virus-infected and healthy cocoa.

All treated plots of these units received applications of *gamma*-B.H.C. at the rate of 4 oz. insecticide per acre in November and December 1959 but subsequently each has been sprayed monthly at half the former rate.

Many plots in areas of neglected infected cocoa have responded spectacularly to the clearing of undergrowth and weeds but there has, so far, been little effect of spraying on the condition of treated plots.

Girth measurements, canopy assessments and yield records of about 10,000 trees have been collected during the past year and will be compared with similar data to be collected in subsequent years.

In seedling growth-rate experiments virulent isolates of the cocoa swollen shoot and mottle leaf viruses have had severe effects on the growth of seedlings infected at the bean stage. In these experiments growth measurements of infected and control plants were recorded

at monthly intervals; after six months the plants were harvested and the wet and dry weights of component parts were recorded. In a typical experiment (see Table 2) simultaneous infection with the Kpeve and severe New Juaben isolates caused a great reduction of all growth attributes of infected seedlings, although each virus alone caused substantial reductions (see Table 3). The results of other experiments (*Quarterly Report* No. 55, p. 5, 1959) have confirmed that, unlike related viruses, multiple infections with unrelated viruses have cumulative effects on the growth of seedlings (*Rep. W. Afr. Cocoa Res. Inst.*, 1958–59, p. 60).

TABLE 2

Dry weight distribution (in gm.) six months after infection (Mean of 30 plants per treatment)

Isolate	*Leaves*	*Stems*	*Tap Root*	*Lateral Roots*	*Total*
Healthy	3.32	1.58	0.78	0.36	6.04
Kpeve	1.87	0.59	0.63	0.18	3.27
New Juaben	1.18	0.76	0.71	0.14	2.69
Kpeve and New Juaben	0.61	0.56	0.59	0.05	1.81

TABLE 3

Percentage reduction relative to healthy controls

Isolate	*Leaves*	*Stems*	*Tap Root*	*Lateral Roots*	*Total*
Kpeve	43.7	62.7	19.2	50.0	45.9
New Juaben	64.5	51.9	21.7	61.1	55.4
Kpeve and New Juaben	81.6	64.6	24.4	86.1	70.0

RESISTANCE AND TOLERANCE (J. W. Blencowe)

The planting of the variety trial E1 (*Rep. W. Afr. Cocoa Res. Inst.*, 1958–59, p. 18) was completed during April 1959. In this experiment the following series of nine crosses have been made between Amazon parents:

T61/1239 × T61/1664
T61/1313 × T61/1403
T62/891 × T62/977
T81/1792 × T81/1880
T81/1880 × T81/1792
T86/956 × T86/1600
T16/613 × T17/359
T17/359 × T17/433
T17/433 × T17/359

The progeny have been planted in plots of twelve trees separated from each other by guard rows of Amelonado cocoa, and there are control plots of both Amelonado and F2 Amazon cocoa. The plots are arranged in randomized blocks, four of which are planted on clear-felled land and four under light forest-trees shade (about 25 medium-sized trees per acre). Most of the treatments are replicated eight times but there was only sufficient material to plant four replicates of a few of the crosses. The experiment occupies about three acres and the seedlings have been planted at a spacing of 8 ft. × 8 ft. with temporary tree-cassava shade. The seedlings have made good growth but have not yet grown to form a continuous canopy.

A VIRUS DISEASE OF COCOA IN SIERRA LEONE (J. W. Blencowe)

Further investigations have shown that the virus occurring at Gandorhun differs little from other mild isolates of the swollen shoot virus occurring in Ghana and Nigeria. Thus characteristic acute and chronic leaf symptoms develop on cocoa seedlings infected by grafting or insects and slight swellings are occasionally produced on stems, stem-tips and tap-roots. The virus has been transmitted by *Planococcoides njalensis* (Laing), *P. concavocerarii* James, *P.* species near *celtis* Strickland, *Planococcus citri* (Risso) and *Ferrisiana virgata* (Ckll.) but, like other isolates of the swollen shoot virus, not by *P. adonidum* L. Using the vector *P. njalensis*, the virus has been transmitted to and recovered from *Ceiba pentandra* Gaertn., *Adansonia digitata* L. and *Corchorus tilocularis* L.

A very mild virus from cocoa at Giehun is graft-transmissible but attempts to transmit the disease with mealybugs failed. The leaf chlorosis on cocoa trees at Wunde appears to be non-infectious.

BLACK-POD DISEASE

STRAINS OF *PHYTOPHTHORA PALMIVORA* (P. D. Turner)

In association with the programme of selection and breeding cocoa types for resistance and tolerance to black-pod disease, work has continued on comparison of isolates of *Phytophthora palmivora* Butler from widely separated areas (*Rep. W. Afr. Cocoa Res. Inst.*, 1958–59, p. 27). During the year, visits were made to Nigeria, Southern Cameroon, Fernando Po and Cameroun for the purpose of collecting isolates and further samples were received from Sierra Leone, Ivory Coast, Gabon, Congo, and Angola. Altogether, 185 isolates from West Africa were collected. The isolates were examined at Tafo under controlled laboratory conditions, and great care was taken to sterilize

all discarded material before disposal. Cultures were obtained mainly from diseased pods or leaf and stem material. The fungus was recovered from pods by direct isolation from the margins of developing lesions, and from vegetative tissue by first inoculating the tissue into healthy pods and isolating from the lesions which subsequently developed. All isolates grew well on 4 per cent. oatmeal agar, and on chemically defined media, such as Czapek Dox, provided they contained a thiamin supplement. Each isolate was examined in three definitive characteristics—physiological, morphological and reproductive—by comparison of development in cocoa pods, dimensions of sporangia, and production of oospores. Differences in artificial culture were also noted.

It was immediately obvious that the dominant cocoa pathogens in the regions east and west of Dahomey were very different, and that different strains of the fungus occurred within West Africa. In the cocoa-producing countries west of Dahomey (Ghana, Ivory Coast and Sierra Leone) the isolates produced lesions in unripe cocoa pods which were typified by a well defined margin and a small amount of aerial mycelium scattered amongst discrete sporangial masses. Isolates from countries east of Dahomey (Nigeria, Southern Cameroon, Fernando Po, Cameroun, and Gabon) produced, for the most part, lesions in pods which had irregular and diffuse margins, a negligible amount of aerial mycelium, but profuse sporangial production giving the infected areas a powdery appearance. Nearly all isolates produced one of these lesion types and, as the distribution based on pod lesion characters was repeated when the characters of sporangial dimensions and oospore production by the isolates were examined, the isolates giving the two types of lesion were, for convenience, referred to as the Ghanaian (G) and Nigerian (N) types respectively. A third type of lesion was produced by two isolates from Sierra Leone and two from Angola; this, referred to as the Angolan (A) type, had a distinct and regular margin and was characterized by the almost complete absence of aerial mycelium and spores.

The growth rate of all isolates in unripe pods, kept in humid chambers at laboratory temperature, was compared with that of the standard isolate from cocoa found at Tafo. Pieces of artificially infected tissue were uniformly inoculated into healthy pods by using a cork borer of standard size. After five days the length and width of the developing lesions were measured and analysed statistically. Almost without exception, isolates of the G type grew at a greater and more uniform rate than any others. A further distinction existed in that G type isolates always developed more rapidly in unripe pods than in ripe ones, whereas this character was variable with other isolates.

Measurements were made of the dimensions of 100 sporangia washed from pods 5-6 days after inoculation, and comparison of these data showed a similar distinction between the groups of isolates. Although little difference was found between mean sporangial length of the fungus groups, the two main groups differed appreciably in width; thus, the mean length: width ratio of the G type was 1.7 and that of the N type 1.3. Sporangia of the A type were similar to the G type but were distorted. The difference in length:width ratio between the two groups is considered to be of diagnostic significance. The distribution of class boundaries for sporangial length was also much less variable within the G group than within the N group of isolates.

Tests for complementary isolates of the pathogen were made by growing paired cultures on 4 per cent. oatmeal agar at 60°F.; after three weeks the cultures were examined microscopically for the production of oospores. Cultures from widely spaced localities within countries were intercrossed, as well as between countries. No single isolate was found to produce oospores, nor were any found in crosses between G type isolates. Oospores were, however, produced in abundance in all paired cultures of G and N type isolates. Oospores were found very occasionally in crosses between N type isolates, and no crosses of any kind could be made with A type isolates. The oospores were of similar dimensions to those produced in paired cultures of 'cacao' and 'rubber' groups of the species. The results confirmed and emphasized the distinction between the groups of isolates.

On account of the important differences found between the G and N isolates, a limited comparison was made with isolates from countries outside West Africa to type the different groups of the pathogen. Isolates were obtained from British Borneo, British Guiana, Ceylon, Dominica, Malaya, Jamaica, New Guinea, Panama, St Lucia, Surinam, Trinidad and Western Samoa, and the co-operation of the various individuals and organizations in these countries is gratefully acknowledged. All isolates produced lesions typical of the G group, and growth rate in pods was, in most instances, approximately equal to that of the Tafo isolate. In sporangial dimensions, isolates from non-West African countries were very similar to the G group fungus, with the exception of those from British Guiana and British Borneo, which resembled those of the N group. Sexually, also, the majority were of the same strain as the G group.

Isolates of *P. palmivora* of the 'cacao' strain were obtained from the Centraalbureau voor Schimmelcultures, Baarn, and grown in paired culture with representative samples of the different groups. No

oospores were produced with the G type isolates, but these were formed in crosses with the N type. The evidence, therefore, showed that isolates of the G type belong to the 'cacao' group of the species, and those of the N type to the 'rubber' group. However, the variation and occasional oospore production within the N group indicates that this is a heterogenous assemblage of isolates which could probably be subdivided into component strains or races. The few isolates of the A type were difficult to classify and may be distinct from *P. palmivora*.

As a result of the investigation, data are now available on more than 230 isolates of *P. palmivora* occurring on cocoa in 22 different countries, representing approximately one-half of the total number of producing countries but including all the more important ones. The N group isolates, the dominant pathogens over a wide area, were quite unlike any others, differing markedly in a number of important characteristics, and seem to be a distinct group.

Occurrence of complementary strains of the pathogen within a territory could result in genetic variation and influence pathogenicity. Hence, the presence of the G type isolate at Ibadan and Umuahia in Nigeria, and at Isobi in Southern Cameroon, could be of fundamental significance. It is unlikely that these are the only localities where the G type occurs and this may, to some extent, explain the variation found in the pathogen. It is possible that the spread of different strains of the pathogen might be effected through distribution of cocoa pods between countries. Surface sterilizing techniques in common use would be insufficient to prevent the later development of very small lesions which are easily hidden in mature pods by damage caused by pests and harvesting. Further spread of the fungus might be reduced by alternative methods of cocoa seed distribution.

It has been shown, therefore, that distinct strains of *P. palmivora* occur in West Africa, two of which are sexually complementary, and that distribution of the two more important strains follows a definite geographical pattern. In the more westerly countries of Sierra Leone, Ivory Coast and Ghana, the only pathogen from cocoa, with the exception of the atypical isolates from Sierra Leone, was of the 'cacao' group of *P. palmivora*. The dominant fungus in the more easterly cocoa-producing countries of Nigeria, Southern Cameroon, Fernando Po and Cameroun was of the 'rubber' group, and the pathogen is not uniform throughout these countries. With regard to selection of cocoa material for resistance and tolerance to black-pod disease, the 'cacao' type isolate was the more virulent in tests with detached pods, and it is possible, but by no means certain, that promising selections from Ghana might give favourable results else-

where. Complementary isolates of *P. palmivora* have not been found on cocoa in countries west of Dahomey. Hence, it would seem advisable to prevent the westerly spread of the 'rubber' group fungus, particularly between the two major cocoa-producing countries of Ghana and Nigeria, as far as possible. In addition, the possibility of a differential response by strains to fungicides widely used in chemical control of black-pod disease, although unlikely, cannot be overlooked.

RESISTANCE AND TOLERANCE (A. L. Wharton)

Data from the 2nd Clonal Trial for the 1959–60 season is given in Table 4.

A second year's set of detailed records will be taken on this trial. However, the differences in black-pod incidence between the two extremes of selection D70 and R15a, b, are so striking that provision is now being made to incorporate progeny from crosses with clones from this trial as parents, in the resistance trial at Mpraeso. Hand pollinations are being started now and land reserved at Mpraeso for planting the seedling progeny in 1961.

TABLE 4

Data from the 2nd Clonal Trial for the 1959–60 season

Selection	*Total pods per tree*	*Total black pods as a percentage of total pods*	*Selection*	*Total pods per tree*	*Total black pods as a percentage of total pods*
D70	30.1	5.9	ICS7	26.2	28.2
U6	27.6	7.2	TF1	25.5	28.3
P30	28.4	10.6	W63	18.8	28.8
D71	17.8	12.0	W41	18.0	32.7
O4	21.2	12.5	E9	26.0	33.6
C22	23.9	13.9	TF2	22.1	34.7
E1	19.2	14.1	A56	26.3	40.9
S21	25.1	15.8	R15a	30.1	45.7
ICS1	25.3	23.0	R15b	18.7	59.9
B1	36.2	28.1			

A five-acre site at Mpraeso (*Rep. W. Afr. Cocoa Res. Inst.*, 1958–59, p. 26) has been cleared of standing timber and old cocoa. Temporary tree-cassava shade is well established and the land is now ready for planting in 1960 the progeny of crosses made last year from the 1st Clonal Trial selections.

IMPORTANCE OF BLACK-POD DISEASE IN GHANA

(J. W. Blencowe and A. L. Wharton)

Black-pod disease in Ghana has been considered of little importance,

compared to other territories in West Africa, like Nigeria, except in restricted localities where cocoa is grown in river valleys and on the ridges of high scarps. In recent years the proportion of pods diseased on fungicide spraying trials has rarely exceeded 25 per cent. and the chemical control methods developed in Nigeria by C. H. Thorold have not given economic returns when applied in Ghana.

It became important to estimate accurately the importance of 'black-pod' on peasant farms in Ghana for two reasons. Firstly, it was not known exactly how representative these losses on field trials were; secondly, work started in 1954 by the Ghanaian Ministry of Agriculture, on the insecticidal control of mirid pests attacking mature cocoa, has given spectacular increases in yield and is now receiving wide application. It was thought that the increased numbers of pods exposed to infection and destroyed might be raised to levels justifying the cost of fungicide treatments.

Method of assessing disease incidence and losses

In 1954 the Cocoa Division of the Ghanaian Ministry of Agriculture introduced a standard record sheet for the classification of harvested crop, and trained large numbers of junior staff in the recognition of pod diseases. The record sheet has since been used on nearly all experiments where crop harvesting was a responsibility of the Cocoa Division. Some of this data has been used to determine the importance of black-pod disease in Ghana.

Estimates have been derived from data collected during the five years, 1954 to 1958, from twenty-three 'Capsid Yield/Recorded Units' of farmer's cocoa. These are the experimental plots on which the control of mirid pests of mature cocoa, by the low-volume application of insecticide sprays, was first demonstrated in West Africa. The plots are chiefly concentrated along the route of the Accra-Kumasi trunk-road. They were chosen originally as being representative of mature cocoa (twenty to twenty-five years in bearing) damaged by mirid pests, without reference to the incidence of black-pod disease. They had, however, to be reasonably accessible and do not include any farms on the ridges of high scarps. It was shown first that a frequency histogram of recorded black pods, expressed as a percentage of total pods for each recorded plot in each of the five years, fits a normal curve of distribution; hence, the plots form a random sample with respect to the incidence of black-pod disease.

Each unit consists of an insecticide-sprayed plot and a control, unsprayed plot contiguous with it, except for one unit which had no control plot. The forty-five plots of recorded cocoa covered a total of 164 acres. Treated plots on each of these units have received

insecticide sprays since September 1954. The units were harvested, and all pods over three inches in length classified, at monthly intervals.

The pod classification data falls into two groups. Firstly, fruits yielding usable beans which included all healthy ripe pods and, from measurements on a sample of 11,600 pods, 44.3 per cent. of all diseased ripe pods. Secondly, completely discarded fruits, comprising the remaining diseased, ripe pods in which the beans had been destroyed (55.7 per cent.), plus all diseased, unripe pods containing immature beans. Total pods harvested are the summation of all healthy and diseased pods and exclude counts of pods destroyed by rodent attack, which were considered to be no longer susceptible to infection and loss directly attributable to black-pod disease.

Results

Immediate regeneration and new growth of sprayed trees followed the initial applications of insecticide in 1954, after the crop for that year had been set. Spray drift and the elimination of mobile mirid pests in the sprayed plots induced a marked improvement of trees in the 'control' plots also. The yield of cocoa on sprayed plots increased from 224 lb. dry cocoa per acre (assuming twelve pods per lb.) in 1954 to an average of 542 lb. over the next four years; comparable figures for the 'control' plots were 202 lb. increasing to 373 lb. per acre.

Nearly 4,500,000 pods were harvested and classified during the five years. Table 5 shows the distribution of this total over the Southern Ghana and Ashanti plots for both the mid- and main-crop periods, and the proportion of pods diseased. An average of 30

TABLE 5

Total pods harvested and proportion of diseased pods on 11 plots in Southern Ghana and 12 in Ashanti, over 5 years

	Total pods	*Diseased pods as a percentage o total pods*		
	(*thousands*)	*Ripe*	*Unripe*	*Total*
Southern Ghana				
Mid-crop	222	12.7	32.5	45.2
Main-crop	1,553	15.7	11.6	27.3
Total	1,775	15.3	14.2	29.5
Ashanti				
Mid-crop	170	25.8	14.8	40.6
Main-crop	2,479	20.9	3.5	24.4
Total	2,649	21.9	4.3	26.2

and 26 per cent. of the total crop was infected on the Southern Ghana and Ashanti plots respectively. The absolute loss of crop was 23 and 16 per cent. when the figures for diseased, ripe pods are adjusted for the proportion which yielded healthy beans. More crop was lost in Southern Ghana because the proportion of diseased, unripe pods was much higher.

Because of the increases in total pods following mirid control, and the differences in yield between plots, it is possible to examine the relationship between the numbers of black pods per acre and the total numbers of pods per acre exposed to infection. The value of the regression coefficient, $b=0.252 \pm 0.013$, shows that for every increase or difference of 1,000 pods 250 might be expected to become diseased by black-pod disease. There was no significant difference between the coefficients obtained when data from the Southern Ghana and Ashanti plots were treated separately ($b=0.28 \pm 0.026$ and $b=0.23 \pm 0.014$ respectively). Further, the slope of the regression lines for individual years did not vary significantly and the regression coefficients were independent of variation in levels of disease between the different years.

The survey data showed a close relationship between the number of diseased pods in the first 'black-pod' outbreak during May, June and July and those in the outbreak on the season's main crop during September to November ($r=0.38$, $t=5.29$ with 168 d.f.). This may be an important factor in reducing the cost of fungicide control measures if sprays concentrated only on the first outbreak reduced sources of inoculum sufficiently to prevent the development of a large outbreak on the main-crop pods.

Discussion

The results from the 'Capsid Yield/Recorded Units' are not now entirely representative of all the farmers' cocoa in Ghana. Since the plots were laid down there has been an enormous increase in crop production from new plantings in the north-west region of Ashanti. The incidence of black-pod disease is probably less in this area where the rainfall is lower than the sixty to seventy inches per annum received by the older cocoa areas. Production in the Eastern Region of Southern Ghana is increasing, despite the continued devastation from cocoa swollen shoot virus disease, but at the end of 1959 the results above apply to 75 per cent. of the main cocoa producing areas, that is, those situated in the sixty to seventy inches per annum rainfall belt.

The estimates of disease incidence and losses are conservative if in fact infections of cherelles (which were not recorded) represent a

direct loss of crop. However, if physiological wilt is a mechanism whereby cocoa trees adjust their final yield to their supply of nutrients and other environmental factors, then it might be expected that the numbers of fruits wilting would be adjusted in response to cherelle losses caused by other factors. Conversely, from the practical view of disease control measures, cherelles protected from disease infection may, instead, wilt and not develop to maturity. Until these problems are clarified the importance of cherelle infections on cocoa trees in Ghana cannot be determined.

There was no evidence, from calculated regression coefficients, to suggest that the proportion of diseased pods alters as levels of yield increase, using either the whole data or that from plots giving yields of over 500 lb. dry cocoa per acre. The survey results can, therefore, be applied to yields of up to about 1,000 lb. per acre (12,000 pods) which is surpassed by eight of the forty-five recorded plots. Beyond this in Ghana it cannot be definitely known, until a source of data becomes available, whether 'black-pod' percentages will alter as levels of yield increase further.

There appears to be no reason why the average yields from farmers' cocoa in Ghana should not be increased from a level of 200 to 250 lb. dry cocoa per acre to a conservative 500 lb. by the efficient control of pests, regular harvesting and the improved management which the 'Capsid Yield/Recorded Units' have received. However, even at this level of yield the numbers of diseased pods to be expected are still probably insufficient to justify the application of fungicide sprays. Table 6 shows the monetary value of average crop losses to be expected from one acre of cocoa in the areas surveyed, at the price paid to the farmer (£G112 per ton dry cocoa) and at an estimated price received by the Ghana Cocoa Marketing Board on the world market (£G250 per ton). The value of these losses can be compared with the cost of £G8.8s per acre, per annum for applications of 1.7 per cent. Perenox applied at three-

TABLE 6

Value (£G's per annum) of average crop losses due to black-pod disease, from trees yielding 500 lb. dry cocoa per acre on 11 plots in Southern Ghana and 12 in Ashanti, over 5 years

Price per ton	*Region*		
Dry Cocoa	*Southern Ghana*	*Ashanti*	*Southern Ghana and Ashanti*
£G112	5·3	3·7	4·4
£G250	12.7	8.2	9.6

weekly intervals by power-sprayers in Nigeria (Thorold, C. H., *Ann. appl. Biol.*, **47** (4), 1959, pp. 708–715). A cost of £G7.8s per acre for an equivalent treatment in Ghana, applied to Estate cocoa yielding an average of 1,000 lb. per acre, has been calculated from the Plantation Manager's records, W.A.C.R.I. These costs do not include the capital cost of power-sprayers but in Ghana these are being purchased on a huge scale by farmers for mirid-control and would be available for applying fungicides. In 1960 it is proposed to examine again the economics of spraying against black-pod disease on sixteen of the survey units, which are expected to give a minimum yield of 450 lb. per acre and subject to a pod disease incidence of at least 20 per cent. of the total pods harvested.

USE OF MINERAL OIL AGAINST BLACK-POD DISEASE (P. D. Turner)

An experiment was started in April 1959 to examine the possible use of light mineral oil to control black-pod disease in the Upper Amazon Spacing and Pruning Trial. The plots were sprayed, using a 'Holder' mistblower, at three-weekly intervals, and pods were harvested at intervals of six weeks. All applications were of the same oil except for that used in the first two applications which differed slightly. Data for the experimental period (April-November) are given in Table 7. The experiment emphasized the effect of spacing on the incidence of disease, and pruning may also be a significant influence in disease reduction. The results, and a determination of any possible effect on yield, are awaiting statistical analysis. The experiment is being continued for a further season.

TABLE 7

Disease control by mineral oil: incidence of black pod

	Spacing	*Replicate number*	*Total pods*	*No. of black pods*	*% black pod*
TREATED	8× 8	3	2,822	396	14.0
	8× 8 P	2	1,644	210	12.8
	10×10	1	859	105	12.2
	10×10 P	4	2,338	175	7.5
	12×12	2	1,200	79	6.6
	12×12 P	3	2,436	142	5.8
	Total	15	11,299	1,107	9.8
CONTROL	8× 8	2	1,545	384	24.9
	8× 8 P	3	2,462	300	12.2
	10×10	4	4,005	587	14.7
	10×10 P	1	1,270	57	4.5
	12×12	3	3,521	476	13.5
	12×12 P	2	867	29	3.3
	Total	15	13,670	1,833	13.4

SAPROPHYTIC SURVIVAL OF *PHYTOPHTHORA PALMIVORA*

(P. D. Turner)

Regular sampling of soil at seven different sites has confirmed previous observations that the soil acts as a source of infection throughout the year (*Rep. W. Afr. Cocoa Res. Inst.*, 1958–59, p. 23), although isolation was less frequent during the earlier, hotter months of the year when there was less rainfall. Monthly samplings of foliage and bark of cocoa trees have resulted in only occasional isolation of the fungus, but detritus collected in crevices, branch junctions, etc., have frequently contained the fungus.

In laboratory tests, sporangia of *P. palmivora* in soil samples have been found to remain viable for at least one year. Viability is affected by the moisture content of the soil, and some variation was found in different soil types tested.

A GALL DISEASE OF COCOA IN GHANA

(A. A. F. Brunt and A. L. Wharton)

Results of the survey (*Rep. W. Afr. Cocoa Res. Inst.*, 1958–59, p. 20) to determine the occurrence and distribution of the gall disease of cocoa in Ghana have been noted (Wharton, A. L. and Brunt, A. A. F., 1959, *Commonwealth Phytopath. News*, **5**, pp. 61–62). The disease has now been successfully transmitted and efforts made to determine its cause. This work was instigated by reports of the alarming spread of the apparently similar 'cushion gall' disease in cocoa areas of South and Central America. Until it is known whether or not this disorder and the galls occurring on trees in Ghana have the same cause it is considered inadvisable to use the nomenclature 'cushion gall' disease for the disease in West Africa.

RESULTS OF THE FIELD SURVEY

With the co-operation of Ministry of Agriculture staff of swollen shoot virus inspection teams it is estimated that approximately half-a-million of the four-and-a-half million acres of cocoa in Ghana were inspected for galls during the period August 1958 to August 1959. Table 8 shows the locations in which gall-bearing trees were found and it will be seen that whereas sixteen trees were widely distributed the additional twenty-eight were concentrated in two farms, eight at Wiowso in Ashanti and twenty at Maase in the Eastern Region of Southern Ghana.

TABLE 8

Distribution of Gall-bearing trees found in Ghana from August 1958 to August 1959

Region	*Area*	*No. of Trees*
Eastern ..	Tafo	1
	Nankese	4
	Kofi Pare	1
	Adidiso	1
	Adonkwanta	2
	Maase	20
Ashanti ..	Goaso	2
	Ankasi	1
	Wiowso	8
Western ..	Wiawso	2 (on T62)
	Assin Prasu	1
	Assin Foso	1 (on T63)
	Total	44

The disorder is of no economic importance and although no cause for alarm, it must be considered of potential importance for two reasons:

1. It is highly infectious in laboratory transmission experiments (see below) although it is not known why the disorder does not spread under field conditions.
2. There is evidence that a similar situation existed in Costa Rica with the 'cushion gall' disease up to about 1955. From that year the disease has apparently broken out and become widespread.

During the survey galls were found on chupons, trunks and fan branches of saplings and trees of both Amelonado and Amazon cocoa but none was found on imported selections of clonal parentage. However, they have been reported on ICS clones at Moor Plantation, Ibadan, Nigeria (Longworth, J. F., *Rep. W. Afr. Cocoa Res. Inst.*, 1958–59, pp. 77–78).

All galls found in Ghana were morphologically similar with the type described in the Western Hemisphere as 'green-point' cushion galls (Hutchins, L. M., Desrosiers, R., and Martin, E., *Rep. Inter-Amer. Inst. agric. Sci.*, Turrialba, 1959, No. 33).

Transmission

The disease has been transmitted by rubbing half-beans with macerated tree and seedling gall tissue and by stroking half-beans

with a moistened squirrel hair brush, previously rubbed over gall (Table 9).

TABLE 9

Rates of transmission by mechanical methods

Source \ Inoculation	*Macerated Gall Tissue*	*Moist contaminated Brush*	*Total*
Tree Galls	8/50	9/18	17/68
Primary seedling galls ..	5/85, 10/10	13/100	28/195
Secondary seedling galls ..	4/10	6/20	10/30
Enlarged cushions of tree ..	0/20, 0/20	0/10	0/50

Numerator indicates the number of infected plants and the denominator the number of plants inoculated.

Half-beans of West African Amelonado cocoa were usually used as test plants but it has been demonstrated that beans from open-pollinated pods of Amazon, Trinitario and Criollo female parentage are also susceptible to infection. The transmission results obtained by inoculating half-beans from these pods with macerated gall tissue from infected Amelonado seedlings are shown in Table 10.

TABLE 10

Mechanical transmission to Amazon, Criollo, Trinitario and Amelonado half-beans

Cocoa Selection		*1st Test*	*2nd Test*	*Total*
Amazon	T 16	3/15	0/13	3/28
	T 2	4/15	2/13	6/28
Trinitario	ICS 1/738 ..	14/15	6/13	20/28
	ICS 89/106 ..	7/10	—	7/10
	ICS 8/109 ..	6/10	—	6/10
	ICS 25/119 ..	7/10	—	7/10
Criollo	194/24 ..	8/10	—	8/10
	195/182	4/10	—	4/10
Amelonado		10/10	4/10	14/20

Numerator indicates the number of infected plants and the denominator the number of plants inoculated.

The disease has been transmitted also by young adults of *Planococcoides njalensis* Laing. The insects were removed to petri dishes from seedling galls with one brush and transferred with other sterile brushes to half-beans at the rate of seven per test plant. Five of 11 inoculated test plants subsequently produced galls.

Seedling galls

Primary galls produced on seedlings after insect and mechanical inoculation of half-beans first appear as an enlargement of the bud in the axil of the attached cotyledon. The gall then increases in size by continued bud proliferation. They can reach up to 1 cm. in diameter within three months after inoculation of the test bean (see frontispiece).

Secondary galls, which have the same structure as primary galls, have developed in the axil of the first leaf or first pair of leaves on some inoculated seedlings which had previously produced primary galls.

Etiology

No gall-forming pests or nematodes were found in galls or adjacent tissues of infected trees and seedlings. Only *Botryodiplodia theobromae* Pat. and *Calonectria rigidiuscula* (Berk. and Br.) Sacc. were isolated occasionally from gall tissue. The isolates of *C. rigidiuscula* were non-infectious when inoculated into meristems of seedlings and mature trees.

Attempts to demonstrate systemic infection in gall-bearing trees and seedlings by graft and insect transmission tests consistently failed. Thus young adults (ten per test bean) of *P. njalensis* failed to transmit the disease from stem pieces of infected trees in twenty-eight tests, and from the apices of young seedlings with primary galls in four tests. None of ten one-year-old seedlings have developed galls sixteen months after each had been grafted with two bark 'patches' from an infected tree. Similarly, the disease has not been graft-transmitted to twenty-seven young seedlings using bark 'patches' (2 per test plant) taken from the stem between primary and secondary galls of infected seedlings.

Macerates of seedling galls in water were passed through a Seitz filter and also centrifuged at 7,000 r.p.m. for ten minutes. Neither the filtrates or supernatant liquid after centrifugation were infective to test beans.

From the appearance of galls it was thought that they were most likely to be caused by a bacterium of the 'Crown Gall' or 'Leafy Gall' type but none of the bacteria isolated from galls have proved infectious. These include one, identified at the Commonwealth Mycological Institute as being similar to *Agrobacterium tumefasciens* (Smith and Townsend) Conn., which has been consistently isolated from gall tissue.

With the object of inducing soft galls on some herbaceous host from which a pathogen might more easily be isolated the following plants

were inoculated with gall extracts: *Helianthus annuus* L., *Nicotiana glutinosa* L., *Petunia hybrida* Vilm., *Phaseolus vulgaris* L. (cultivar Canadian Wonder Improved) and *Vinca rosea* L. No galls were produced on these plants. Further attempts are being made to isolate a bacterial or fungal pathogen.

The results of the field survey show that the West African gall disease is at present of little economic importance in Ghana. However, the ease with which it has been transmitted in laboratory experiments and its close resemblance to the very important disease in the Western Hemisphere indicate that it should be considered a disease of potential importance. The Ministries of Agriculture in Ghana and nearby countries have been advised that all galls found on trees should be removed and destroyed by burning. There is, however, no immediate cause of alarm since the disease is not more widespread now than it was thirty-seven years ago. Galls on cocoa have been known in Ghana since 1923, affected trees found in our survey were widely distributed and none was found on trees grown from imported vegetative material. The disease is therefore thought to be indigenous to West Africa. Removal of galls is therefore unlikely to result in the complete eradication of the disease, but should prevent the local spread of infection which has apparently occurred at Maase and Wiowso.

MEALYBUG STUDIES

JOINT W.A.C.R.I.-DIVISION OF AGRICULTURE MEALYBUG CONTROL TRIAL

(P. F. Entwistle)

Insect counts in the experiment at Oyoko on the control of swollen shoot disease vectors through the elimination of their attendant ants by the use of dieldrin (see *Rep. W. Afr. Cocoa Res. Inst.*, 1957–58, p. 31 and 1958–59, p. 30), were terminated in December 1959. No further insecticidal treatments were made during the year.

Populations of both ants and mealybugs recovered more rapidly than after the first double dieldrin treatment. This may have been due to the fact that dieldrin was not sprayed into the canopy in the second treatment and also that several food farms enclosed by the treated area could not be sprayed. These may have acted as foci from which reinfestation of the plot took place internally.

Table 11 compares the rates of return of populations of *Planococcoides njalensis* (Laing) adults after the first and second treatments and shows that estimates of numbers by counts to hand height compared favourably with counts made on complete trees, though at numerically different levels.

TABLE 11

Rates of recovery of populations of adult P. NJALENSIS *after the first and second Dieldrin treatments in the Oyoko Trial*

1st Treatment			*2nd Treatment*		
Fortnight	*Adult* P. njalensis *per* 100 *trees*		*Fortnight*	*Adult* P. njalensis *per* 100 *trees*	
	Hand height counts	*Complete tree counts*		*Hand height counts*	*Complete tree counts*
1	289.7	—	42	138.6	4,177.5
2	296.3	—	43	91.5	1,958.7
3	197.8	1,405.2	44	54.4	140.0
4	81.3	942.5	45	37.5	76.5
5	23.1	461.7	46	21.4	33.0
6	1.2	342.0	47	7.5	33.0
7	1.9	261.5	48	2.5	23.5
8	3.5	143.5	49	2.6	118.2
9	1.6	94.2	50	28.3	219.2
10	0.0	58.7	51	86.3	130.2
11	0.0	41.5	52	87.9	30.0
12	0.0	62.2	53	43.0	31.2
13	0.0	81.2	54	13.1	49.5
14	0.0	93.2	55	20.0	46.0
15	0.0	87.5	56	14.8	27.2
16	0.0	83.2	57	9.0	34.5
17	0.0	102.0	58	2.3	126.5
18	0.0	111.7	59	12.0	207.5
19	0.0	117.2	60	21.4	205.5
20	0.0	115.0	61	18.1	539.0
21	0.3	111.5	62	18.0	1,029.7
22	3.3	126.2	63	50.2	1,038.5
23	14.6	126.2	64	95.0	1,084.5
24	38.5	157.5	65	96.6	1,875.0
25	47.2	201.2	66	80.3	2,331.2
26	23.4	155.0	67	74.2	2,205.2
27	16.4	128.7	68	58.7	2,160.5
28	26.6	166.5	69	31.8	1,795.2
29	19.3	183.0	70	49.7	2,123.7
30	27.0	266.5	71	111.4	2,263.7
31	54.1	382.7	72	135.5	1,421.0
32	69.8	665.7	73	132.3	1,398.2
33	59.7	873.7	74	133.8	1,822.1
34	45.1	562.5	75	141.7	1,651.0
35	50.6	487.5	76	162.8	790.5
36	68.5	782.7	77	157.7	227.5
37	105.7	1,570.7	78	104.8	1,152.5
38	130.5	2,863.7	79	69.8	2,762.5
39	101.6	3,313.2	80	88.5	2,686.0
40	92.8	2,804.2	81	117.9	1,434.5
41	136.4	3,522.5			

Unexpected trends were recorded for virus incidence in the treated area during the year. In treatment D, where both visibly infected trees and trees in physical contact with them were removed, incidence rose almost to pre-treatment levels. Up to the end of the second year

after the initial insecticidal treatment this area had shown a striking decrease in virus incidence (see *Rep. W. Afr. Cocoa Res. Inst.*, 1958–59, p. 30). In treatment C, where visibly infected trees alone were removed, only slightly more infected trees were found than in the previous year.

It is uncertain to what extent these data are the result of the poor degree of vector control following the second dieldrin application, or reflect virus transmission through the recovery of the *P. njalensis* vector populations prior to retreatment.

Trends of virus incidence during the coming year, together with data on the latency period of the viruses concerned, may give meaning to this picture.

THE INCREASE OF MINOR PESTS OF COCOA FOLLOWING APPLICATION OF DIELDRIN (P. F. Entwistle)

Good ant control with a consequent fall in numbers of *Planococcoides njalensis* (Laing) was obtained at the Oyoko Trial (*Rep. W. Afr. Cocoa Res. Inst.*, 1958–59, p. 30) following the application of 1 lb. actual dieldrin, as 20 per cent. emulsible concentrate per acre, usually as a 20-gallon spray with motorized mistblower sprayers. The use of the dieldrin spray, however, caused a marked increase in certain minor pests.

Following the second double application of dieldrin (1 lb. per acre in June and August 1958), to control ants in the Oyoko ant/mealybug experiment, three other insects became unusually prevalent early in 1959. These were (1) *Eulophonotus myrmeleon* Feld. (Lepidoptera, Cossidae), a borer of the main trunk and branches (2) an unknown lepidopteran (probably two species, both belonging to the Metarbelidae, one of which has now been identified by the British Museum as *Metarbela* sp. ? *rava* Karsch.) whose larvae makes a web, usually at branch junctions, beneath which the bark is devoured, the stem often ring barked and a short gallery excavated into the heart wood (Entwistle, Johnson and Dunn; *Nature*, 26th December 1959, Supplement Vol. 184) and (3) *Tragocephala nobilis* F. var. *castnia* Thoms. (Coleoptera, Cerambycidae), the larvae of which makes a gallery often over three feet long in chupons and fans. It would appear that this generalized application of dieldrin has a greater effect on the parasites and predators of these pests than on the pests themselves.

Table 12 compares the incidence in sprayed and unsprayed areas (200 acres each) eight months after the second spray.

TABLE 12

Changes in incidence of three pests of cocoa in relation to a dieldrin sprayed area

Distance from sprayed area	*Percentage Trees Attacked*		
	E. myrmeleon	*Unidentified Metarbelid species*	*T. nobilis v. castnia*
Within sprayed area	19.2	27.8	6.2
50-100 ft.	6.1	8.3	4.5
100-150 ft.	3.1	4.6	3.8
500-550 ft.	1.5	3.3	1.8
1 mile (unsprayed control area) ..	0.6	0.3	2.8

Estimates were made from the ground only and therefore are minimal. Counts taken along diagonal transects on treated and control areas were made on 800 trees in each area. Counts at the three different distances from the margin of the treated area were on 600 trees at each distance (in three batches of 200 at separate sites).

JOINT W.A.C.R.I.-DIVISION OF AGRICULTURE ANT CONTROL TRIALS: METHODS OF APPLICATION AND FORMULATION

(P. F. Entwistle and K. B. Armstrong)

In order to prevent minor pest increases following the general application of dieldrin, a new trial to test the efficiency of different methods of application and methods of formulations of dieldrin to control ants has been laid down at Bunso, Bosuso and Osino areas. It was expected that the following treatments made in the present trial would, by their localized application, achieve ant mortality comparable to the general spray, without disturbing the natural predator/prey and parasite/host association. Twenty-five, twenty acre plots, were aggregated into five groups of five plots matched for numbers of ant nests. These groups were then randomly allocated to the following treatments:

A. Application of 1 lb. actual toxicant in 20 gallons of water per acre (0.5 per cent. solution) by motorized mistblower to the first 8-10 ft. of trunk, the volume applied being geared to tree density rather than acreage.

B. Application of 1 lb. actual toxicant in 10 gallons of water per acre (1.0 per cent. solution) by baffled motorised mistblower so that spray is directed to the lower trunk and ground litter with minimal upward drift into the tree canopy.

C. Application of 1 lb. actual toxicant in 10 gallons of water per acre, by pressured knapsack sprayers to a 2 foot deep zone round the trunk of each cocoa tree. It is envisaged that where areas of primary and secondary forest occur within a plot, they will have to be treated with motorised mistblowers as in "A".

D. Application of a 10 per cent. dieldrin Urea-formaldehyde lacquer with a paint brush as a band around each trunk. Forest trees treated as in "A".

E. Untreated controls.

Plots with treatments A, B and C were given double application with 8 weeks interval, on 30th September, 1959 and on 28th November, 1959 treatment D was given a single application on 12th October, 1959.

Six, fortnightly pre-treatment counts of ant population as individuals, organised columns, and active nests were made on 300 trees, forest and cocoa, in each plot. Counts of mealybug population to hand height, were also made on 150 trees in each plot. Further counts have been made at fortnightly intervals and will continue as such for the duration of the experiment.

The following two tables give the treatment results to March 31st, 1960.

TABLE 13

Ant population: as numbers of Crematogasterine and Pheidoline nests per 1,500 trees—fortnightly running sum (Treatment D=1,200 trees)

Treatment	*Pre-treatment*	*March 1960*	*% Original population*	*Corrected % original population*
A	777	75	9.7	7.7
B	748	180	24.1	19.3
C	793	193	24.3	19.4
D	535	133	24.9	19.9
E	737	923	125.2	—

TABLE 14

Mealybug population: as numbers of P. njalensis *individuals per 750 trees—fortnightly running sum (Treatment D=600 trees)*

Treatment	*Pre-treatment*	*March 1960*	*% Original population*	*Corrected % original population*
A	2,459	33	1.3	3.8
B	3,805	1	0.26	0.08
C	3,195	5	0.16	0.5
D	1,887	174	9.2	27.1
E	4,864	1,651	33.9	—

The incidence of the minor pests, *Eulophonotus myrmeleon* Feld, *Tragocephala nobilis* F. v. *castnia* Thoms. and the Metarbelid Webber have also been recorded on all plots during mealybug counts. From pre-treatment assessment of no damage, increase in damage up to 31st March 1960 has occurred only with *E. myrmeleon.*

SYSTEMIC INSECTICIDES (K. B. Armstrong)

Considerable work has been carried out on the screening of nine systemic and semi-systemic insecticides through mealybug mortality, following soil, leaf and spray application, at several concentrations, to nine-twelve months seedlings. Preliminary indications are that Rogor 40 and Metasystox (Mesyston being comparable to Metasystox), are likely to be the most useful in the field with regard to foliar application and it is intended to commence field trials with these.

Taste tests, for occurrence of taint, chemical analysis of wet and fermented/dried beans are being performed on Rogor and Metasystox and the results are awaited.

TABLE 15

Days after treatment		*Average No. of leaves*	*No. of c.c.s applied/ leaf*	*Detectable distance (inches)*		
				Minimum	*Maximum*	*Mean*
1	Fan	13.6	0.85	8	18*	14
	Chupon	18.2	0.63	3	24	19
3	Fan	16.4	0.52	12	30	25
	Chupon	22.4	0.73	0	96†	30
7	Fan	14.4	0.82	12	75†	45
	Chupon	23.0	0.78	0	78	43
14	Fan	12.8	1.09	36	106†	72
	Chupon	12.0	1.22	0	102*	54

* Sample tissue ended at this distance with radioactivity still evident.
† Sample tissue ended at this distance with radioactivity very evident.
Further trials with soil, leaf and bark application to seedlings have also been carried out.

A pilot experiment to follow the uptake and translocation of Rogor 40 by cocoa has been initiated. Mature leaves at the distal ends of fans and chupons were painted with tagged material (P^{32}) and assessment was made after twenty-four hours, three days, seven days and 14 days with an end window counter. Five fan branches

and five chupons were used for each assessment period and samples of tissue were taken from the treated area along the length of the fan or chupon to its junction with the main trunk (see Table 15). Detection was of the radioactive element and not of actual Rogor itself.

CAPSID STUDIES

JOINT W.A.C.R.I.-DIVISION OF AGRICULTURE CAPSID CONTROL TRIALS

(C. G. Johnson and E. Dunn)

The series of trials in Ashanti begun in 1958 to compare the effectiveness against capsids of Endrin, *gamma*-BHC and Aldrin, at rates approximately proportional to cost (see *Quart. Rep., W. Afr. Cocoa Res. Inst.*, No. 50), have now been terminated.

There were three treatments replicated five times; (1) Endrin at ½ oz. per acre, (2) *gamma*-BHC at 1 oz. and (3) Aldrin at 2 oz. In addition to the unsprayed controls, five plots were given the standard *gamma*-BHC spray treatment (4 oz. initial double application followed by 1 oz. double application retreatment). All the three treatments were given an initial double application of insecticide at twice the quoted rate in July-August 1958.

Analysis of the data collected shows that Endrin at the ½ oz. rate is significantly superior to *gamma*-BHC at 1 oz., however, the difference between *gamma*-BHC at 1 oz. and Aldrin at the 2 oz. rate is not significant. Table 16 gives a summary of the percentage of damaged trees following three retreatments. The table shows clearly the marked decrease in the control plots in damaged trees after the second and third retreatment. This is explained partly, by the fact that all the control plots were adjacent to the treated areas and consequently, as a result, the capsid population was reduced by insecticidal drift and partly, because a number of the farmers had sprayed the control plots unofficially after observing the spectacular results of capsid control in the treated areas.

LABORATORY ASSESSMENT OF INSECTICIDES (K. B. Armstrong)

Several insecticides have been screened in laboratory tests using fifth instar nymphs of *Distantiella theobroma* Dist. as assay material. Insecticide solution has been applied to 9 cm. glass petri dishes by means of a Potter Tower. The deposit is dried in a 30°C. oven for two hours and the capsids then placed in contact with the deposit for one hour. A twenty-four-hour recovery period in a glass chimney with a half-pod as food supply is allowed before mortality counts are taken. Five or more concentrations of insecticide spray have been used in order to obtain useful regression lines. Approximately 125

Table 16

Capsid control experiment—Ashanti

1st Inspection				2nd Inspection			3rd Inspection		
Dates of retreatments	*Type of treatment replicated* × 5	*Total trees*	*% of damaged trees*	*Dates of retreatments*	*Total trees*	*% of damaged trees*	*Dates of retreatments*	*Total trees*	*% of damaged trees*
14/1/59 1/6/59	Endrin ½ oz.	5,689	7.8	12/8/59 27/10/59	5,654	1.8	13/1/60 24/2/60	5,613	0.1
9/1/59 26/5/59	*g*-BHC 1 oz.	6,564	11.2	31/7/59 23/10/59	6,530	2.2	1/1/60 12/2/60	6,497	0.7
10/1/59 27/5/59	*g*-BHC 1 oz.	6,918	10.8	3/8/59 26/10/59	6,846	4.0	4/1/60 15/2/60	6,816	0.8
13/1/59 29/5/59	Aldrin 2 oz.	6,903	13.6	10/8/59 19/10/59	6,859	2.0	11/1/60 12/2/60	6,813	0.8
15/1/59 2/6/59	Control	7,777	44.7	4/8/59 27/10/59	7,619	15.0	5/1/60 16/2/60	7,513	5.8

insects are used to supply data for one such point. Comparison of the insecticides is made at their L.D. 50 when the slopes of the lines are similar.

The following insecticides have been screened for activity against capsids, Aldrin; DDT; Dieldrin; Dipterex (0,0 dimethyl—2:2:2—trichloro-1-hydroxy-ethylphosphonate); Endrin; Lindane; Metasystox; Ortho-dibrom (0,0 dimethyl-0-(1,2-dibromo-2,2-dichloroethyl phosphate); Pyrethrins; Dimethoate as Rogor 40 *N*-methyl-(0,0-dimethyl-dithiophosphoryl acetamide); Baytex (Bayer S.1752); (0,0 - dimethyl - 0 - 4 - (methylmercapto) - 3 - methylphenylthiophosphate); Sevin (1-napthyl *N*-methylcarbamate); Shell W.L. 1650.

The results of this screening based solely on comparison of L.D. 50 values are, in descending order of efficacy—Sevin 50 W.P., Endrin 20 E.C.> Dipterex 80 sol. P., Metasystox 50 E.C., Sevin 85 Sprayable, S.1752 50 E.C., Rogor 40 E.C., W.L. 1650 15 E.C.> Orthodibrom 8 64.5 E.C., 6 per cent. Pyrethrins Water Miscible Formulation, Dieldrin 20 E.C.> Gammalin 20 E.C.> Aldrin 40 E.C.> DDT 25 Miscible Liquid. It is to be stressed that as the slopes of the regression lines were not all equal, different relative efficiencies occurred at the L.D. 90 values. Endrin and Sevin 50 were still the most efficient capsicides at this level. Efficiency in the field need not follow the above succession, for formulation and method of application are of considerable importance. Potential persistence in the field can be assessed to a certain extent in the laboratory and it is intended to test the more promising insecticides in this way.

PERSISTENCE OF INSECTICIDES (K. B. Armstrong)

A preliminary field trial to investigate the persistence of deposits of the chlorinated hydrocarbons, *gamma*-BHC, Aldrin and Endrin at two dosage levels, after application to mature cocoa has been carried out. A satisfactory technique using a 62°/82° B.P. petroleum ether wash has been established for extraction of surface residues.

Harvests of 150 leaves from each plot were made after twenty-four hours, three days, seven days and fourteen days following spraying with 1 oz. and 2 oz. Endrin, 2 oz. and 4 oz. Aldrin and 2 oz. and 4 oz. *gamma*-BHC in 5 gallons/acre. There were three replicates per treatment, each plot being $\frac{1}{10}$ acre in size. Application was also made to the same plots at a later date and a harvest of each treatment, one hour after application, was made.

The surface extract was concentrated, 4 cc. of the concentrate

evaporated off inside small glass vials and estimates of insecticide residue made by bio-assay using *Drosophila melanogaster*. Direct bio-assay with harvested leaves was made by caging *Distantiella theobroma* with leaves in lamp glasses.

The results of this trial and of the chemical analysis carried out on Endrin and Aldrin residues will be reported later.

MINOR PESTS

NURSE SHADE V. NO SHADE EXPERIMENT (E. Dunn and M. R. Smith)

A field experiment has now been set up to determine the effects caused by removal of shade from young cocoa. In particular, comparisons of various insects populations, especially lepidoptera, are being made on shaded and deshaded cocoa.

The two principal treatments in the experiment are (1) plantation cocoa with tree cassava nurse shade and (2) plantation cocoa with all shade removed. Provision has also been made for the application of three spray treatments after a pre-treatment period of, say, one year. The statistical design of the experiment is a 6×6 latin square (spray treatments included). Each plot measures 10×8 trees. This includes a guard row around each plot, leaving forty-eight experimental trees per plot, spaced 10×10 ft. Several different varieties are involved; the varietal boundaries run right across the experimental area parallel to, but not coinciding with, the long edges of the plot boundaries.

The cocoa was planted in 1958. The nurse shade in those plots destined to become unshaded was considerably thinned in mid-November 1959 and was then reduced more gradually until all shade had been removed by early March 1960.

LEPIDOPTERA (M. R. Smith)

The following lepidoptera were bred from larvae found attacking cocoa at Tafo. Collection and breeding were carried out by Mr P. F. Entwistle, who compiled the following list in June 1958. Identifications were carried out by the Commonwealth Institute of Entomology.

ARCTIIDAE

Diacrisia rattrayi Rths.
D. aurantiaca Holl.

NOCTUIDAE

Prodenia litura F.
Erias biplaga Wlk.
Lophocrama phoenicochlora Hmps.
Characoma stictograpta Hmps.
Anomis leona Schaus

LYMANTRIIDAE

Stracena fuscivena Swinh.
Orgyia basalis Walk.
Euproctis sp.

NOTODONTIDAE

Scalmicauda sp.

GEOMETRIDAE

Neocleora sp.

PYRALIDAE

Polygrammodes hirtusalis Walk.

LASIOCAMPIDAE

Leipoxais sp. nr. *peraffinis* Holl.

LIMACODIDAE

Semyrilla lineata Holl.
Parasa viridissima Holl.

TORTRICIDAE

Enarmonia (*Laspeyresia*) sp.*

XYLORICTIDAE

Odites sp.

In addition to the above list the following lepidoptera have since been recorded attacking cocoa in Ghana.

EUCOSMIDAE

Archips occidentalis Walsm. det C.I.E.

PYRALIDAE

Sylepta retractalis Hmps. det M.R.S. and C.I.E.

LASIOCAMPIDAE

Leipoxais rufobrunnea Strand det C.I.E.
Leipoxais sp. ? *crenulata* B. Bkr. det C.I.E.

ACRAEIDAE

Acraea pharsalus Ward det C.I.E.
Acraea rogersi Hew. det C.I.E.

LYCAENIDAE

Hypokopelates eleala Hew. det C.I.E.

* A better specimen of this species has since been determined by the Commonwealth Institute of Entomology as *Olethreutes* sp. nr. *praecedens* Wals.

GEOMETRIDAE

Colocleora divisaria Walk. det M.R.S. and C.I.E.
Hyposidra smithi Warr. det C.I.E.

SYNTOMIDAE

Syntomis dilatoralis Hmps. det C.I.E.

ARCIIDAE

Rodogastria luteibarba Hmps. det M.R.S. and C.I.E.

NOCTUIDAE

Eudrapa mollis Wlk. det C.I.E.

LYMANTRIIDAE

Crorema mentians Walk det M.R.S. and C.I.E.
Argyrostagma niobe Weym. det M.R.S. and C.I.E.
Orgyia mixta Snellen det C.I.E.
Euproctis dewitzi Grunb. det M.R.S. and C.I.E.
Euproctis melanopholis Hmps. det C.I.E.†
Euproctis fasciata Warren det M.R.S. and C.I.E.
Euproctis lepidographa Hmps. det C.I.E.
Euproctis lyoma Swinh. det C.I.E.
Euproctis xanthomelaena Holl. det C.I.E.

LIMACODIDAE

Omocena convergens Hering det M.R.S.
Latoia vitelina Karsch det M.R.S.
Casphalia flavicollis Wlk. det M.R.S.
Baria elsa Druce det M.R.S.

Species of unknown or doubtful identity have not been included in the above list. The list is incomplete because many species found attacking cocoa have not yet been identified. Those species which have been identified by the Commonwealth Institute of Entomology are marked 'det C.I.E.' and those identified at W.A.C.R.I. are marked 'det M.R.S.'.

The survey of lepidopterous pests of cocoa will continue.

Parasites

The Commonwealth Institute of Entomology have made the following identifications:

Amicrocentrum sp. (Hymenoptera, Braconidae), a parasite of the larval stages of *Eulophonotus myrmeleon* Feld. and *Meteoridea* sp. (=*Benema* Nixon) (Hymenoptera, Braconidae), a single specimen of which has been reared from a pupa of a moth belonging to the Metarbelidae and probably to the genus *Metarbela*.

† Previously identified by the Commonwealth Institute of Entomology as *Euproctis* sp. nr. *discipuncta* Holl.

CERAMBYCIDAE

The egg parasites of *Tragocephala*, mentioned in the previous Annual Report, have now been identified by the Commonwealth Institute of Entomology as:

Aprostocetus sp. nr. *diplosidis* Crawf. (Hymenoptera, Eulophidae).

POD FUMIGATION (K. B. Armstrong)

The use of calico bags painted inside and out with plastic emulsion paint as liners has overcome the damage encountered (*Rep. W. Afr. Cocoa Res. Inst.*, 1958–59, p. 38) when using polythene. Polythene liners have, however, been successfully used when stout paper sacks are substituted for the normal jute cocoa sacks. The same concentration (1 oz. toxicant per cubic foot) has been used successfully as in the initial trials.

Further work has been carried out with Propylene oxide (1:2—Epoxy-propane) in the hope that its use as a fumigant would control not only all arthropods in and on the pods but also any fungal spores or mycelium, particularly Phytopthora infestans, the causal organism of black pod. Unfortunately control of mycelium artificially inoculated into pods was achieved only at a concentration which completely inhibited bean germination (0.96g/litre). A concentration of 0.16g/litre propylene oxide gave 100 per cent. mealybug mortality but only 60 per cent. bean germination and above this concentration a rapid fall off in germination occurred.

As in this experiment, it was of the utmost importance to achieve maximum germination of beans, the use of propylene oxide as a fumigant for cocoa pod phyto-sanitation cannot be recommended for either mealybug or black-pod control.

NEMATODE STUDIES

(E. Dunn)

Root knot eelworm, *Meloidogyne* sp. has been found on cocoa seedlings at W.A.C.R.I. This eelworm causes discrete galls on the roots. Small swellings may also occur on the stem of the plant just above the ground-level. On dissection these swellings are found to contain live specimens of eelworms.

Specimens have been sent to Dr M. T. Franklin at Rothamsted Experimental Station for identification, she states the eelworms may be either an unusual form of *Meloidogyne incognita* var. *acrita* Chitwood or a new undescribed sp.

A survey is being made of the cocoa seedlings on W.A.C.R.I. to find the extent of this nematode infestation.

ESTABLISHMENT AND MAINTENANCE TRIALS

(T. H. R. Hall)

SPACING TRIALS

Amelonado Cocoa

In the Amelonado Spacing Trial, planted twelve years ago, 7½ ft. × 7½ ft. spacing has again provided the highest yield, but with the 4 ft. × 4 ft. spacing a very close second best as can be seen from Table 17.

TABLE 17

Yields from the Amelonado Spacing Trial for the 1958–59 and 1959–60 crops

Spacing	15′×15′	12′×12′	10′×10′	7½′×7½′	7½′×6′	6′×6′	5′×5′	4′×4′
Equivalent density (trees per acre)	193	302	435	774	968	1,210	1,742	2,722
Pods/tree								
1958–59	91.13	62.39	53.10	32.29	22.17	16.36	13.11	8.08
1959–60	49.4	59.5	54.3	31.6	22.6	18.6	13.1	8.8
Dry cocoa per acre								
1958–59	1,465.6	1,570.2	1,924.7	2,112.7	1,788.4	1,469.7	1,903.2	1,832.8
1959–60	795	1,487	1,969	2,007	1,828	1,877	1,912	1,997

Table 18 gives the distribution of pods on the tree.

TABLE 18

Amelonado Spacing Trial—distribution of crop 1959–60
Percentage of total pods in canopy and on trunk

Spacing	15′×15′	12′×12′	10′×10′	7½′×7½′	7½′×6′	6′×6′	5′×5′	4′×4′	*Mean*
Trunk	57.7	53.9	54.1	72.4	71.5	73.1	82.9	87.9	62.4
Canopy	42.3	46.1	45.9	27.6	28.5	26.9	17.1	12.1	37.6

It can be seen that a higher proportion of the crop is borne on the trunk than on the canopy and the ratio varies according to the spacing.

The set back anticipated as a result of shade removal in 1959 does not appear to have materialized as the overall yield has increased from 148,824 pods in 1958–59 to 153,312 pods for the period 1st April 1959 to 29th February 1960 (3 per cent. increased). Table 18, shows, however, that there is a substantial decrease in the wider spaced cocoa, while a small increase has occurred in the closer spacings. Whether or not these figures are a true reflection of effect of complete shade removal is difficult to judge.

Amazon cocoa

The results of the Amazon Spacing Trial are shown in Table 19 and it will be seen that the 10 ft. × 10 ft. spacing has again given the highest yield. The overall yield of the plot shows an increase of just over 9 per cent. compared with last year despite the fact that this year's results are for an eleven-month period and not twelve months as hitherto.

TABLE 19

Yields from Upper Amazon Spacing and Pruning Trial 1958–59 and 1959–60

Spacing	8′×8′		10′×10′		12′×12′	
Equivalent density (trees per acre) ..	680		435		302	
	1958–59	1959–60	1958–59	1959–60	1958–59	1959–60
Unpruned						
Pods/tree	18.9	25.8	40.9	43.5	53.21	55.1
Dry cocoa in lbs. per acre	1,071	1,423	1,486	1,581	1,339	1,388
Percentage Crop in canopy ..	×	74.3	×	74.1	×	
Pruned						
Pods/tree	16.6	20.1	30.63	30.3	46.62	40.7
Dry cocoa in lbs. per acre	941	1,129	1,113	1,093	1,168	1,062.5
Percentage Crop in canopy ..	×	77.25	×	77.14	×	83.2

Records of the distribution of the crop on the cocoa tree, shows that three-quarters of the crop is borne in the canopy.

Unlike Amelonado cocoa there is little difference in distribution with spraying.

PRUNING TRIALS

Amelonado cocoa

In the second establishment trial the pruned plots gave a significantly lower yield than those which were not pruned, whereas a yield of 14,400 pods was realized from those pruned, 22,300 pods came from the unpruned plots.

For the first time the small two-acre pruning trial has produced a measurable yield. Although small, the difference in favour of no pruning is apparent.

Amazon cocoa

In the Amazon Spacing and Pruning Trial the unpruned cocoa gave a yield, higher by 34 per cent. than that pruned, the difference being significant at the 1 per cent. probability level.

A tree forming experiment was laid down in 1959 on three-year-old Amazon cocoa to compare the effects of pruning and no pruning on the yield. The aim on the pruned plots is to produce a single stemmed tree 5 ft. to 6 ft. high, at which height strong fan branch growth is allowed to develop. In the unpruned plots the height of the cocoa will not be restricted, but only one leader will be allowed to mature. The first pods were harvested during the year, and the small yield is again indicating that pruning limits the yield.

SHADE EFFICIENCY TRIAL

In July, a trial to test the efficiency of Plantain, Tree Cassava and Plantain, Banana, and Tree Cassava was laid down in a randomized eight replicated block design. Girth and height measurements and sample weight of weeds will be recorded to assess the efficiency of the different light regimes. The height and girth recordings taken in October have shown no variations from which conclusions can be drawn.

PLANT BREEDING AND SELECTION

(D. R. Glendinning)

YIELDS AT W.A.C.R.I. IN 1959–60

Yields for 1959–60 in the main botany plots are compared to those for 1958–59 in Table 20. The general increase in yield mentioned in the 1958–59 Annual Report continues.

TABLE 20

Pods harvested from the main botany plots

	Year planted	*Experimental area*	1958–59	1959–60
Trinidad introductions ..	1945	12.3 acres	122,500	141,000
1st clonal trial ..	1947	4.4 „	58,000	65,000
2nd clonal trial ..	1948 (Sept.)	2.8 „	30,000	39,000
8th progeny trial ..	1952	1.9 „	19,500	31,000
9th progeny trial ..	1954	5.2 „	68,000	89,000

Some individual yields are recorded in Table 21.

TABLE 21

Performance of some selections 1959–60

	Spacing	*Age from planting out (years)*	*Estimated yield dry cocoa (lbs./acre)**	
			Potential†	*Net*
Introductions				
Trinidad introductions area ..	14′×14′	15		
T60			2,500	1,730
T11			2,100	1,810
T76			2,100	1,480
T56			2,000	1,710
Clones				
1st clonal trial	10′×10′	13		
A36			2,300	1,740
K5			2,000	1,500
ACU85			1,800	1,600
B2			1,800	1,500
S27			1,800	1,450
2nd clonal trial	8′×8′	11½		
D70			2,160	1,990
B1			2,100	1,610
R15			1,990	1,250
ICS7			1,980	1,430
U6			1,850	1,720
3rd clonal trial	12′×12′	4		
T12			510	220
T79/501			495	405
T60/887			420	330
Crosses				
8th progeny trial	8′×8′	8		
WAE4			2,700	2,000
WBE3			2,500	1,800
WAE5			2,400	2,000
WAE2			2,300	1,450
WAE3			2,000	1,650
WBE2			2,000	1,100
9th progeny trial	10′×10′	6		
WEB1			2,000	1,500
WAE11			2,000	1,550
WEB3			1,750	1,300

* Based on an assumed conversion rate of 40% on fermenting and drying the wet beans.

† 'Potential' yield is based on the assumption that all pods harvested are useable. 'Net' yields are the amounts remaining after deduction of all diseased and damaged pods. As some cocoa is recoverable from damaged pods the actual yields will be between these two values. Reports prior to the 1958–59 season gave only the potential yields.

All plots other than the 9th Progeny Trial have received routine fertilizer dressings, and in some the shade has been much reduced. The 9th P.T.A. is being maintained under shade and without fertilizer so as to correspond with peasant farm conditions.

THE RELATIONSHIP OF GROWTH TO YIELD

A report on the relationship of growth rates to yields in the 9th Progeny Trial has been prepared for publication elsewhere. Briefly, as would be expected, the faster growing varieties come into

Table 22

Ghana Series I Trials

			Increase in stem diameter (cms.)							*Order of ranking*							*Mean ranking*
			Bechem	*Akaa*	*Poano*	*Juaso*	*Bunso*	*Oyoko*	*Biene*	*Bechem*	*Akaa*	*Poano*	*Juaso*	*Bunso*	*Oyoko*	*Biene*	
		1955–56	1.13	1.08		1.54	2.35	1.02		1	1		1	2	1+		1.3
	T60	1956–57	1.16	1.82		1.81	2.07	1.64		2	1		1	1	1		1.2
		1957–58	1.56	—		2.36	1.91	1.70		2	—		1	3	1		1.75
		1955–56	1.03						1.20	4						3	3.5
Amazon	T79	1956–57	1.06						1.78	3						2	2.5
varieties		1957–58	1.33						1.93	3						4	3.5
					0.82	1.46			1.32			2	2			2	2.0
	T12				1.59	1.71			1.68			2	2			4	2.67
					2.35	2.20			2.18			1	4			2	2.33
			1.12	0.97	0.75	1.45			1.46	2	5	3	2			1	2.6
	T85		0.95	1.55	1.24	1.66			2.08	4	5	4	3+			1	3.5
			1.70	—	1.69	2.35			2.89	1	—	4	2			1	2.0
				1.04			2.42	1.02			2			1	1+		1.5
	T17			1.65			2.05	1.45			4			2	3		3.0
				—			2.48	1.28			—			1	4		2.5
					0.66							4					
	N38				1.14							5					
					1.64							5					
Local types			1.07	0.99	0.54	1.35	2.00	1.66	1.08	3	4	5	4	4	3	4	3.86
	TF1		1.29	1.66	1.28	1.66	1.98	1.53	1.71	1	3	3	3+	4	2	3	2.79
			1.18	—	1.70	1.93	1.77	1.65	1.90	4	—	3	5	4	2	5	3.83
			0.84	1.04		1.27	2.07	0.67	0.98	5	2		5	3	4	5	4.0
	S72		0.63	1.81		1.50	2.02	1.31	1.43	5	2		5	3	4	5	4.0
			0.89	—		2.23	2.42	1.38	1.96	5	—		3	2	3	3	3.2
Amazon					1.17							1					
×	WEB				1.86							1					
Local type hybrid	2				2.33							2					
Year planted			1954	1954	1954	1954	1953	1953	1954								
Degree of significance of varietal differences in the trials																	
		1955–56	N.S.	N.S.	0.1%	N.S.	N.S.	1%	0.1%								
		1956–57	5%	N.S.	5%	N.S.	N.S.	N.S.	0.1%								
		1957–58	1%	—	1%	N.S.	1%	N.S.	0.1%								
Significant difference of variety means (at 5%)																	
		1955–56	.23	.14	.13	.21	.34	.17	.13								
		1956–57	.39	.37	.43	.36	.36	.33	.21								
		1957–58	.40	—	.39	.33	.43*	.47	.20								
Degrees of freedom for 'error'			12	12	12	12	6	6	12								

NOTE: Akaa 1957–58 has not been studied as excessive drought losses rendered the data difficult to interpret.
The Bunso and Oyoko trials are Latin Square designs; the others Randomised Blocks.

* Bunso 1957–58 significant difference based on 12 DF, the rows and columns not being significant and being pooled into the error.

bearing earlier and give good early yields. Of perhaps more profound significance is the observation that the yield obtained is highly correlated with the reduction in the rate of growth after the commencement of bearing. It is possible that those varieties still growing vigorously may later slow in growth and give good yields, but yields are unlikely to be better than in the earlier bearing varieties for, at the close spacings used in Ghana, no advantage is likely from the trees becoming larger.

THE GHANA SERIES I TRIALS

A series of trials was planted in 1953 and 1954 to compare Amazon varieties to local types. Each trial contains four or five varieties, of which two are local types and two or three are Amazon types. The Amazon varieties are planted at 10 ft. × 10 ft. and the local varieties at 7 ft. × 7 ft. There are four plots each of twenty-five trees of any given variety in a trial, and all trials are on Division of Agriculture cocoa stations.

It will be seen (Table 22) that only TF1 is common to all trials; unfortunately it does not offer a very good basis of comparison, as the seed of this variety was obtained by open pollination so that each pod could have had a different male parent. The seed of other varieties was secured by hand pollination.

Table 22 shows the increases in stem diameter from year to year for 1955 to 1956, 1956 to 1957, and 1957 to 1958. By 1958 some trials (especially the 1953-planted Bunso trial) were in fairly heavy bearing, and this modified the vegetative growth rates. By 1957–58 inter-tree competition may also have been important, and the difference in spacing between the Amazon and local types may accentuate the distortion of relative growth rates caused by this. However growth over the periods 1955–56 and 1956–57 should not have been seriously affected by either competition or bearing.

It will be seen that T60 is outstanding, and that in general, the Amazon varieties outgrow the local types.

Some varieties seem to do better at some sites than at others, relative to the other varieties, e.g., S72 does better relative to T85 at Akaa than at Biene. This particular variety v. site interaction was significant in 1955–56 and in 1956–57. No other such interactions were significant against a pooled 'error' over all the trials before 1957–58, when T12 v. T85/Poano v. Biene was significant at $P=0.01$, and a number of other interactions at $P=0.05$. The possibility must be borne in mind that these interactions in 1957–58 may have derived from changes in the relative growth rate due to commencement of bearing, the faster growing trials commencing bearing before the others.

Further information emerged when the variety v. site interactions of pairs or groups of varieties were studied over three or more trials. In particular, a significant interaction of TF1 and S72 over six trials in 1956–57 proved to be due to TF1 being less checked by adverse conditions than was S72. A similar situation was detected with T85 and TF1. It must be remembered though that TF1 is open-pollinated, and does not offer a good standard.

Explanation of these variety v. site interactions in terms of preferences for particular characteristics of soils or climate have not yet been attempted.

NURSERY EXPERIMENTS

It appears from studies such as that on the 9th P.T.A. reported above that there is a relationship between the early growth of cocoa varieties and their subsequent yields. It seems therefore that it may be possible to obtain some indication of the probable performance of a variety from the vigour of seedlings in the nursery. Experiments have been carried out to test this possibility by comparing varieties of known performance as seedlings, and attempts have also been made to obtain information of use in the breeding programme.

1. *Experiments to test the validity of the technique*

The 2nd Progeny Trial, planted in 1942, contains progenies obtained by self-pollinating certain clones. Some of these same clones were self-pollinated to provide seed for these experiments. Growth records were taken at intervals, and in most cases wet or dry weights of the seedlings were recorded eventually.

The following points emerged:

1. The weight of the seed, which differs considerably between varieties, greatly influences the initial size of the seedling (cf. Goodall, D. W., *Ann Bot* N.S. *13*, 1-21, 1949).

2. Differences between the varieties in rate of growth are readily observed.

3. Clear differences between the varieties in the relationship of the three characters mostly studied, stem diameter, stem height and number of leaves were found, but the differences were small and in these experiments the order of ranking was the same for all three characters, and also for seedling weights.

The first experiment, in 1957–58, gave an order of ranking K5, TF1, S45, A62, and the second in 1958–59 gave S45, TF1, A72, A62. The reason for the difference in the relative positions of TF1 and S45 in the two years is not known. In cumulative yields over several years TF1, K5 and A72 are among the best in the 2nd Progeny Trial,

S45 is about average, and A62 is one of the poorest. Apart from the anomalous placing of S45 in 1958–59, the results of the seedling experiments seem hopeful.

2. *Experiments employing the technique*

(*a*) *Inbred generations and their value as parents*

Some third generation inbreds from the clones were included in the above experiments, and proved much inferior to the first-generation inbreds discussed above. In subsequent experiments second-generation inbreds were crossed together, the parent clones were crossed, and both inbreds and parent clones were crossed to a standard Amelonado variety. Third-generation inbreds (selfed progenies of the second-generation inbreds) were again included, and again were much inferior, but the crosses of the second-generation inbreds to each other or to Amelonado on the whole appeared as satisfactory as the crosses involving original clones. It seems therefore that inbreds, though themselves of reduced vigour, may be satisfactory parents.

(*b*) *Comparison of a cross to its reciprocal*

Suggestions have arisen that a cross and its reciprocal are not always of equal vigour. This apparent effect could in some cases arise from differences between the parents in seed size.

Comparison was made using an Amazon clone Na32 and an Amelonado S45 as parents. Each seed was sown in a separate basket, and the baskets intermingled. At the first recording, in January 1959, differences though suggestive were not significant. At the second recording, in May 1959, stem diameters differed significantly but the difference was completely negatived by covariance on the weight of the seed at planting. The experiment has been carried forward as a field planting.

(*c*) *Exploration for hybrid vigour*

This was a relatively large experiment involving many parents which were crossed together in various combinations, as convenient. Pods were sown over a period of several months as they matured so direct comparison between the crosses was not possible. The technique used was to compare them to open pollinated Amelonado as a control. Where possible forty seedlings of each cross were compared to ten Amelonado, the forty seedlings of a cross being obtained eight each from five pods. The seeds were sown in a continous bed of baskets, five baskets wide, the Amelonado control seed being sown in any of the five baskets of a cross-row at random and the other four

baskets containing seeds under test. It proved, unfortunately, that seedlings in the outer rows did much less well than in the inner rows, and that by randomizing the position of the control seedling rather than placing it in a fixed position in the row its value had been much reduced. The effect of position in the row varied somewhat in different parts of the nursery, and it has not been thought worthwhile to attempt to correct for it. In consequence it has not been possible to obtain standard errors for the relationships of the controls to the crosses under test.

Growth rates were determined both for the crosses and the controls, and the various crosses were compared to each other by the ratios of their growth rates to those of the controls planted with them. These growth rates were obtained in two ways. Measurements were made on the progenies in January and again in March 1959, and a value obtained for the differences between the log. of (diameter^2 × height) at these dates. Most of the seedlings were dug up and weighed in June, and a logarithmic growth rate calculated from that weight and the weights of the bean at sowing, converted to estimated dry weights. By both methods arbitrary values are obtained, but as the values were not used directly, the ratios between the cross and its controls being used in each case, this is not thought to be important.

There was some agreement, though on the whole not a very good one, between the values obtained by the two methods, and by both methods almost all crosses proved to outgrow the Amelonado controls. In some cases where two or more parents were each crossed to a number of others it was possible to demonstrate significant variation between the parents in the vigour of crosses involving them, e.g. Table 23.

TABLE 23

Calculated growth rates of crosses divided by those for the controls sown with them. Growth rates based on estimated dry weights of the seeds at sowing and of the seedlings after several months

	T55	T7	T6	*Means*
T12	1.23	1.18	1.14	1.18
Na32	1.13	1.15	1.04	1.11
T89	1.21	1.15	1.07	1.14
Means	1.19	1.16	1.08	1.14

Analysis of Variance	M.Sq.	F
T55, T7, T6	90.8	13.76, significant at 5%
T12, Na32, T89	44.1	6.66, almost significant
Interaction	6.6	

To obtain a general picture, the average value for the growth rate relative to the control in all crosses involving a particular parent has

been extracted. Table 24 gives the values for parents evaluated in four or more crosses.

TABLE 24

Growth rates relative to controls averaged over four or more crosses involving each parent

	On stem volumes	*On weights*	
Na32	1.16	T7	1.34
T12	1.14	T12	1.21
T6	1.10	T55	1.19
T55	1.10	T102	1.16
T102+T7	1.09	Na32	1.14
T89	1.07	T6	1.14
K5	1.05	K5	1.12
		T89	1.12

T102 and T7 are related, T102 being a selfed progeny and T7 an open pollinated progeny from the same tree. T7 is clearly outcrossed to a distinct type. The values on stem volumes were very similar, but on weights rather distinct. T89 gave an apparently higher growth rate when used as a male parent than when used as a female; this could have been an artificial effect resulting from the very large size of the T89 beans. The seedlings with this parent as female were large from the outset, but appeared rather slow growing. The values shown above are the average of some crosses with T89 as male and some with it as female.

(*d*) *Comparison of individual Amazon types and inter-Amazon hybrids as parents*

A comparison of the cross of Nanay 32 to K5 and of an individual from a progeny Na32 × Parinari 35 to K5 was inconclusive, but the advantage appeared to be to the cross Nanay 32 × K5, suggesting that the use of individual Amazon populations in crosses to other types may be at least as satisfactory as using inter-population hybrids as parents, as has been done in the varieties at present under consideration for issue.

A similar experiment in which Nanay 32, Parinari 35, and a hybrid individual Nanay 32 × Parinari 35 were each crossed to a chosen Amelonado has been carried forward as a field planting.

(*e*) *Inter-Amelonado hybrids*

An attempt to determine if hybrid vigour can be obtained in crosses between Amelonado or Amelonado-like types from various sources was inconclusive, and not especially hopeful. It has been carried forward as a field planting.

REPORT ON THE NEW W.A.C.R.I. VARIETIES

A report entitled 'New W.A.C.R.I. varieties, the present position' has been circulated to the Divisions of Agriculture and others who are concerned in the assessment of the varieties. This report details the codes used for the varieties and their parentage, their yields in the

plantings at Tafo, gives reports on their quality, and reports their performance in trials away from Tafo.

No attempt will be made to reproduce the report here, but the following points may be recorded:

1. *Quality*

Many of the varieties have been submitted to the British, American, and Swiss manufacturers for assessment, and in general the assessments are favourable. Some varieties appear to be fully satisfactory on the basis that they are virtually indistinguishable from West African Amelonado, so that they can be issued without damaging the uniformity of the exported crop.

2. *Trials away from Tafo*

Trials of the new hybrids were planted in Ghana in 1956 and 1957, and in Nigeria in 1957 and 1958 (Series II trials). Although some of the Ghana trials are already coming into bearing, most records yet available are on growth. Stem diameter increases range from about 1.25 cm. per year in the poorest trial to about 2.5 cm. per year in the best. Although there are suggestions in the data that some varieties have preferences for particular sites, these have not yet been proved significant. In general, the same varieties appear to be among the best almost everywhere, and this holds out hope that it may be possible to issue these varieties widely, which will greatly simplify the problem of seed distribution.

F1, F2, F3 TRIAL

The planting of this trial, comparing the F1, F2 and F3 generations of an Amazon hybrid T82 (Nanay 32 × Parinari 35), was reported last year. The F1 generation was obtained by hand-pollination between clones of the parent trees, while the F2 and F3 generations were open-pollinated with opportunity for outcrossing to other types of cocoa. The F3 generation, which was obtained as pods from a number of Division of Agriculture seed-production plots, is that which is being received and grown by the farmer.

Although the seed was sown over a relatively short period of time (30th November to 18th December 1957) the seedlings of the different generations showed significant variation in size when planted out in May 1958. These differences may have been due partly to differences in vigour being expressed by their growth in the nursery, and probably partly to differences in the conditions under which they were grown in various parts of the nursery. The order of size then was F1, F3, F2.

Measurements of the plants have been taken at three-monthly

intervals since planting. The F1 generation is now largest by a wide margin, and the F2 is slightly larger than the F3. Due to the initial differences this in itself is not regarded as conclusive, but analysis on the rate of increase in stem diameter (which, being roughly linear with time, is not affected by the size at planting) shows the increase in the F1 generation to be significantly greater than in the others at the one in one thousand level. (Covariance analysis of the increase in stem diameter from planting to August 1959 on the diameter at planting also shows the variation between the generations to be significant at P=0.001.)

Records of the number of leaves and the length of the longest leaf on each plant are also being maintained. In August 1959 the F1 had the most leaves and the F3 least, while the leaves were largest on the F1 and smallest on the F3. The differences in number of leaves in August 1959 are significant almost at P=0.01 and by covariance on the number at planting are fully significant at P=0.001.

It had previously been thought that the ample opportunity for outcrossing to distinct types in the original planting of T82 at W.A.C.R.I., Tafo, and the equally great opportunity in the Division Agriculture's seed-production plots where various types are deliberately interplanted, would have served to maintain hybridity and equally high levels of vigour. However it is now clear that the F1 generation of T82 is superior to the others in vegetative vigour, and it also appears that the F2 is superior to the F3 generation though the latter difference has not yet proved statistically significant.

The breeding programme is aimed at present at the production of F1 hybrids of high vigour for issue to the farmers. These will be produced by interplanting clones of the parent trees and harvesting the pods from a self-incompatible clone (see 1958–59 Annual Report). The likelihood of a substantial reduction in vigour if later generations are grown by the farmers is underlined by the results of the above experiment. It will be necessary therefore to advise against the growing of further generations, and to attempt to persuade the farmers to return to the Division of Agriculture for all their seed requirements.

PLANT PHYSIOLOGY

(R. G. Hurd)

COPPER AND BORON DEFICIENCIES IN COCOA

A nutrient culture experiment previously described (*Quart. Rep. W. Afr. Cocoa Res. Inst.*, No. 52) has been concluded and the results are being published. The copper and boron deficiency symptoms obtained agree quite well with those of previous investigators. Particularly interesting was the presence of swellings on some copper

deficient plants which were shown to contain aberrant xylem tissue.

Swellings of this type were first mentioned by Lockard Vamathevan and Thamboo (*Nature*, **184**: 75–76, 1959). It was found that the anatomy of swellings produced by swollen shoot virus differed from those found on copper deficient shoots. The production of swellings and other anatomical changes indicated that copper deficiency results in interference with the transpiration stream.

CHERELLE WILT IN THE SHADE AND MANURIAL TRIAL

Data on cherelle wilt in the shade and manurial trial are being prepared for publication elsewhere. The most important result has been that the increased yields have not resulted from a decrease in cherelle wilt; the percentage of cherelles which wilted being the same in all treatments. The production of flowers and cherelles was much greater in the better treatments, and, cherelle wilt being a constant percentage, yields are proportional to the flower and cherelle production. This supports the conclusion reported earlier (*Rep. W. Afr. Cocoa Res. Inst.*, 1958–59, p. 44) that attempts to reduce the percentage wilt and thereby increase yield are unlikely to be successful.

OBSERVATIONS ON COCOA ROOTING SYSTEMS

Cocoa roots can be divided into (1) tap root, (2) lateral roots and (3) sinker roots, extending down from the lateral roots. In an experiment to find the relative importance of these different root systems roots of two of the above categories were removed or exposed (protected by a layer of plantain leaves) during the dry season (with five trees in each treatment). It was found that no matter which one of the three root systems was left intact, after an initial loss over the first two weeks of some 50 per cent. of the leaves, the leaf-number remained constant. At the end of the dry season leaf-numbers increased with the new flush. This indicates that the conventional division of roots into feeding and water absorbing roots is misleading in that all the roots appear to be able to function adequately in both ways.

UPTAKE OF RADIOACTIVE PHOSPHATE BY COCOA

Uptake by roots

The uptake of radioactive phosphate (P^{32}) by young seedlings was investigated. One hundred ml. of a solution containing a hundred microcuries (100 μc) of 0.0005M $KH_2P^{32}O_4$ was poured into a circular trough made in the soil three inches from the stems of ten-month old Amazon seedlings. After two hours no activity could be detected in the stem; after four hours it was just discernible and

within twenty-four hours it was systemic throughout the seedlings (approximately 21 in. tall). The activity in the leaves after twenty-four hours was measured and the greatest activity was found in the youngest leaves, the least in the oldest leaves (although these were nearest the source of labelled phosphate). There was no appreciable difference between the amount of activity in the leaves of shaded and unshaded plants after twenty-four hours.

Uptake of phosphate by the roots was, therefore, rapid and systemic in distribution.

Uptake by leaves

The movement of P^{32} painted on the leaves of mature trees was investigated prior to more extensive work using radioactive insecticides.

The last mature flush leaves of fan branches were painted with 0.0005M $KH_2P^{32}O_4$, at a concentration of 2 μc/ml. and the activity traced down the stem. After two days activity could be detected no further than two feet down the branch from the point of application. Two per cent. of the applied P^{32} was retained in the painted leaves as repeated washings in a carrier phosphate solution with added detergent did not remove this fraction. Some P^{32} moved into the stem but within inches of the painted leaves the activity dropped to a low level. Radioactivity falls off logarithmically with distance from painted soy-bean leaves (*Arch. Bioch. and Biophys.*, **36,** 383, 1952) and this appears to be true here also.

Uptake by pods

The P^{32} was measured in the beans of mature but unripe pods near the painted leaves. Whether the pod was proximal or distal to the painted area approximately 0.1 per cent. of the P^{32} was found in the beans after seven days. The uptake into ripe pods was much less, as found in the previous experiment in which P^{32} was applied to the soil.

The pods themselves were also painted with the $KH_2P^{32}O_4$ solution. In this case ripe pods absorbed as much P^{32} as unripe pods, although the results were variable. There was no further increase in activity in the beans after three days. Uptake of P^{32} over a three-day period by pods of widely different ages varied from 1–3 per cent. of that applied.

It was observed that in mature but unripe pods the parenchyma destined to break down to form mucilage does not turn brown on exposure to air whereas the pod wall parenchyma, which is identical in appearance, rapidly turns brown when exposed to air. It is

suggested that the enzyme causing parenchyma breakdown may inhibit development of the brown colour on exposed tissues.

Further, in bean dissection, it was observed that the testa of the bean is about twenty cells thick, is well vascularized, and has several distinct regions. The innermost region contains two one-cell thick lignified layers and the rest of the tissue is predominantly thin walled.

It was noted that the process of pith breakdown started around the beans, indicating that the enzyme initiating breakdown is formed in the bean, probably in the outer testa.

VEGETATIVE PROPAGATION

(T. H. R. Hall)

CUTTING AND ROOTING EXPERIMENTS

In February, the collection in the clonal nursery was used in two management studies to investigate the cutting production and rooting potential of a number of W.A.C.R.I. clones. The representatives of the clones in the nursery were all coppiced, and by the end of the year 75 per cent. of the stools were displaying vigorous regeneration. All suitable cutting material will be recorded, while the ability of the cutting material to root will also be assessed.

SOIL FERTILITY, IRRIGATION AND SHADE

LABORATORY INVESTIGATIONS (R. K. Cunningham)

Laboratory work investigating the effects of degrees of exposure on the chemical and physical status of a forest soil and the study of forest soil nitrification has been completed. These investigations will be reported in detail elsewhere.

FIELD EXPERIMENTS

The study of Amelonado yield variability mentioned in the last Annual Report (p. 55) has now been published in detail (Cunningham and Burridge, *J. hort. Sci.*, 1959, **34**, 229-237).

Yield data from the Uniformity Trial (old reference A6, now a fertilizer trial G1) planted in 1947 (*Rep. W. Afr. Cocoa Res. Inst.*, 1947–48, p. 77) have been used to illustrate the large soil variability that can occur within a small area sited on a single soil series (Burridge and Cunningham, *Emp. J. exp. Agric.*, *28*, 327-334. 1960).

Major-nutrient experiments (R. K. Cunningham and R. W. Smith)

The yields obtained from the Shade and Manurial experiment

(K1) for the season 1959–60 continue to show the effects of shade removal and fertilizer application and are noted in Table 25.

TABLE 25

Shade and Manurial Trial
Yield expressed in lb. dry cocoa per acre

Treatment	1958–59	1959–60
Shade—no fertilizer	958	756
No shade—no fertilizer	2,348	2,178
Shade—fertilizer	1,211	906
No shade—fertilizer	3,091	3,088
Sig. diff. at P=0.05	304	220
Sig. diff. at P=0.01	461	333
Sig. diff. at P=0.001	741	534

At two former village sites on the Square Mile (F1 and I2) Amazon cocoa has been successfully established and large responses to both a mixed NPKMg fertilizer and mulch have been obtained. In the third year after planting out, the yields in pods per tree were: Control 0.62, Fertilizer 4.4, Mulch 8.9, Fertilizer+Mulch 7.2.

Significant responses to phosphate have been obtained in several experiments at Tafo as well as from joint experiments with the Ghana Division of Agriculture. A further series of ten joint trials have been planned to start in April 1960 to ascertain the best rate of application and the residual effect of triple superphosphate, and to compare triple superphosphate with a West African rock phosphate.

Micro-nutrient experiments (R. K. Cunningham)

No significant response has been obtained in the experiment (*Rep. W. Afr. Cocoa Res. Inst.*, 1957–58, p. 60) on the Old Station at W.A.C.R.I. where four different methods of copper application were employed. There has also been no detectable response to micro-nutrients at Adonkwanta where a subtractive design was used to test the effect of soil application of iron, manganese, copper, zinc, boron and molybdenum. Both experiments have been terminated.

Establishment and soil protection experiments
(R. K. Cunningham and R. W. Smith)

The Amazon cocoa established on clear felled land in Block A at W.A.C.R.I. (A6) has given high yields after three years in the field (overall mean of 37.3 pods per tree) and the NP and NPKMg treatments have given significant responses (P=.01) of 34 per cent. and 50 per cent. respectively.

The shade trees and cocoa have both established well on the thirty-two acres of clear felled land in Blocks K and O at W.A.C.R.I. The preparation of this area has been fully described elsewhere. (Allison and Cunningham, *World Crops*, 1959, **11**, 311-313). The experiment planned will contain four replications of three degrees of shade, and within each shade treatment, a 3^3 NPK factorial experiment. Fertilizer treatments will not be applied until two or three years' yield records are available for calibration.

The experiment designed to test the effect on establishment of various cover crops and a mulch, planted in May 1958 (H5) has been reported in detail (Cunningham and Smith, *Trop. Agriculture, Trin., 38*, 13-22. 1961).

A small experiment to compare the establishment of Amelonado and some Amazon varieties on clear felled land was started in May 1959. Plots containing twenty-five trees were replicated four times. Light shade was provided by tree cassava and a Guatemala grass (*Tripsacum laxum*) mulch was applied. In addition, one ounce of a 15-15-12 NPK fertilizer was placed in each planting hole and the seedlings were sprayed fortnightly with Endrin. The stem diameters measured after nine months in the field are shown in Table 26

TABLE 26

Stem diameters 15 cms. above ground

Cocoa	*Centre*	*Conditions under which growing*	*Mean stem diameter in cms.*
Mixed Amazons ..	W.A.C.R.I. Block H	Light shade, mulch, NPK fertilizer	2.32
Amelonado	W.A.C.R.I. Block H	Light shade, mulch NPK fertilizer	1.61
Mixed Amazons ..	W.A.C.R.I. Block H	Light shade, mulch, *no* fertilizer	1.98
Mixed Amazons T12, T60, T85* ..	Juaso	Forest shade, *no* mulch, no fertilizer	1.31
Amelonado*	Juaso	Forest shade, *no* mulch, *no* fertilizer	1.18
Mixed Amazons T79, T60, T85* ..	Bechem	Forest shade, *no* mulch, *no* fertilizer	1.72
Amelonado*	Bechem	Forest shade, *no* mulch, *no* fertilizer	1.44
Mixed Amazons T79, T85, T12* ..	Biene	Forest shade, *no* mulch, *no* fertilizer	1.48
Amelonado*	Biene	Forest shade, *no* mulch, *no* fertilizer	1.18

* Data supplied by the *Plant Breeder*, W.A.C.R.I.

where a comparison is made with seedlings grown for approximately the same period under forest shade at several different sites and also with seedlings planted at the same time on the same soil with mulch, but without fertilizer.

Soil Moisture and Irrigation (R. W. Smith)

The irrigation treatments have been maintained during the year on experiment H4a, and in January 1960 the hand watering system was superseded by an overhead sprinkler system using an oscillating spray line. The differences in height, stem diameter, and leaf number and size reported in the 1958–59 report have steadily increased. The trees are coming into bearing, the two irrigated treatments producing a significantly greater number of flowers than the control. Irrigation has not altered the rhythm of flushing, but the flush peaks are not so marked, nor the depressions so deep, as those on the control plots.

An irrigation trial commenced in January 1960 on one third of the shade and manurial trial at W.A.C.R.I. (K1). The water is applied by an overhead sprinkler system using a turbo-spray line. It is intended to maintain the soil moisture at or near field capacity throughout the year.

POT EXPERIMENTS (R. K. Cunningham and J. C. Burridge)

The experiment described previously (*Rep. W. Afr. Cocoa Res. Inst.*, 1958–59, p. 54) has been followed by three further experiments using the same technique (controlled shade, side protection, continuous watering from beneath and frequent applications of insecticide). These experiments (i) 2^4 NPKMg with shade gradually reduced from about 85 per cent. to no shade over eighteen weeks, (ii) 2^2 inert mulch and fertilizer, with no shade and (iii) 2^3 shade, water and side protection, will be fully reported later.

One result, the much better growth of unshaded seedlings than that previously reported, has already been discussed (Cunningham and Burridge, *Ann. Bot.*, N.S. *24*, 458-462, 1960). Spectrographic analysis revealed a ten-fold increase in manganese uptake (from about 200 ppm to 2,000 ppm in leaves on a dry weight basis) resulting from the use of ammonium sulphate as a source of nitrogen; this was probably due to the change in soil pH which was lowered from approximately pH 7.5 to pH 6.5.

GROWTH ANALYSIS OF COCOA SEEDLINGS UNDER DIFFERENT DEGREES OF SHADE (R. G. Hurd)

An analysis of the growth of Amelonado seedlings at three months and at seven months age has been carried out under artificial shade

screens supplying different levels of shade. Data was obtained by harvesting fifty seedling samples under each level of shade at the beginning and at the end of a roughly three-week period in September-October, and again in February-March.

The seedlings, which had been raised in baskets under 40 per cent. shade, were planted in their final positions at one to two months age. They were set wide apart to reduce mutual shading to a minimum. The soil used was 'Koforidua series' topsoil from the W.A.C.R.I. Square Mile; it was thickly mulched with grass to keep its temperature approximately constant. No fertilizer was added, but hand-watering with rainwater was done on any day without natural rainfall, and the seedlings were sprayed regularly with 2 oz. Endrin and 2 oz. *gamma*-BHC insecticides. The total light received by the plants was recorded by an oxalic acid actinometer method, the flasks being suspended within the foliage so that the values obtained are equivalent to the average light received by the leaves. It is salutary to notice that the total light received under the nominal 40 per cent. shade regime in February-March is almost equal to that received by the fully exposed plants in September-October, and that the 80 per cent. shade regime in February-March is equivalent to about 50 per cent. in September-October.

The data are presented in Table 27.

TABLE 27

Growth analysis of seedlings over 3-week periods at ages of 3 months and 7 months, at different light intensities

Nominal % shade	*RGR g/g/week*		*NAR g/sq. dm./week*		*Amount of light over exptal period**	
	3 mnths.	*7 mnths.*	*3 mnths.*	*7 mnths.*	*3 mnths.*	*7 mnths.*
0%	0.095	0.098	0.087	0.196	1.43	2.64
20%	0.115	0.117	0.087	0.215	0.82	1.91
40%	0.117	0.131	0.091	0.162	0.69	1.23
60%	0.120	0.161	0.079	0.165	0.45	0.77
80%	0.112	0.065	0.077	0.064	0.33	0.51

* Light values represent the number of mls. of oxalic acid decomposed over the twenty-day period starting with 10 mls. of N oxalic acid and 0.5 mls. of 0.001 M uranyl acetate.

Records were made in Sept.-Oct. for the 3 month seedlings and Feb.-March for the 7-month-old plants

Discussion

The values for the net assimilation rate (NAR) and for the relative growth rate (RGR) are much higher for the seven-month old plants than for the three-month old plants. Goodall (*Ann. Bot.*, N.S. **14**, 1950) also observed an increase in NAR over the first six

months of growth. It could be argued that the increase he observed was due to the increase in light available to the plants over the period of the experiment, from August to February, mean sunshine increasing from two hours to six hours per day over this period. This explanation is not adequate in the present case however, for plants receiving comparable amounts of light as measured by the actinometers had higher RGRs and NARs at seven months than at three months. (Records of soil moisture, soil temperature and mean air temperature were similar over the two periods.) The difference is therefore fairly certainly associated with the age of the seedlings. A possible explanation is that it is associated with the degree of maturity of the leaves, for a higher proportion of the leaves on the older plants were mature.

It will be noticed that the highest RGRs for both three- and seven-month old plants were recorded under 60 per cent. shade (equivalent to .45 and .77 units of light received as recorded by the actinometers). Thus for these seedlings the best growth was under considerable shade although for the older plants the optimal amount of light was higher than for the younger plants. In practice with the additional factor of self-shading becoming progressively more important, optimal light values may be expected to become even higher as the plants grow. Indeed, Cunningham and Burridge (1960) have observed with seedlings planted one foot apart, that a good growth rate was maintained when initially heavy shade was steadily reduced as the plants grew, no shade being provided at all after 4½ months from planting.

The highest NAR for the three-month old plants is also under a good deal of shade (40 per cent., equivalent to .69 light units received) but for the seven-month plants the highest NAR is under 20 per cent. shade (1.91 units of light). Thus the older plants have a much higher light requirement for optimal photosynthesis. It appears, however, that some other component of growth is inhibited by this level of insolation in this experiment since, as mentioned above, the highest RGR of these plants is at a lower light intensity. In the experiment of Cunningham and Burridge quoted above, fertilizers and an automatic water supply to the roots resulted in an optimal RGR at relatively higher light values, in agreement with this suggestion.

The predominantly low light values which proved to be optimal for growth in this experiment may appear to be at variance with the data from the Shade and Manuarial trial (see elsewhere in this Report), where highest yields and better growth (from trunk measurements) take place without shade. However, the average light received by the leaves of unshaded cocoa is only about

60 per cent. of full daylight in this experiment, due to the mutual shading effect of the leaves, while the average light received by the foliage of shaded trees is only about 15 per cent. of full daylight, thus well below the optimum indicated by these seedling experiments. It may also be that greater flushing activity in the unshaded cocoa, due to higher canopy temperatures,* has contributed to the greater canopy development observed, and this greater canopy development could result in a high growth-rate even if the rate of assimilation of the leaves were slightly lower.

COCOA PREPARATION AND QUALITY

EFFECT OF KILLING AMELONADO COCOA BEANS BY FREEZING BEFORE FERMENTATION (R. H. Kenten)

The purpose and preliminary results of experiments on the effect of killing cocoa beans by freezing before fermentation was described in the last Annual Report (*Rep. W. Afr. Cocoa Res. Inst.*, 1958–59, p. 57). The results indicated that beans previously killed by freezing and then fermented and sun-dried in the usual way gave cocoa of acceptable quality.

Subsequent experiments have shown that an acceptable product could often be obtained from the main-crop, and less frequently from the mid-crop, by freezing, thawing and sun-drying beans without any period of fermentation. So far, the quality of only a few samples has been assessed by independent panels. A continental firm has reported on a series where 50 lb. lots of frozen and thawed cocoa beans were fermented for 0–4 days and then sun-dried. The triangle test method of assessing the quality of the cocoa was used. All the samples were acceptable and the frozen and thawed sun-dried unfermented sample was found to be not significantly different from the Grade I Accra standard. Two samples of frozen and thawed sun-dried unfermented cocoa have been found acceptable by an English firm.

Experiments where small lots of beans have been frozen and thawed and then incubated at 37° for varying periods before air drying in the laboratory have indicated that cocoa of good quality can be made in this way. An incubation period of 24–48 hours is satisfactory with Amelonado cocoa.

It is possible that this method may be suitable for the small scale processing of cocoa beans from new material for quality assessment, but it would be preferable to standardize the drying and accordingly a method of drying by infra-red radiation will be tried.

* Greenwood and Posnette (*J. hort. Sci.*, 1950) found a temperature of 83°F. to be critical for the development of flushes of new leaves.

The results suggest that once the bean has been killed by cold the desirable changes can take place at temperatures much lower than those found in normally fermenting cocoa. Furthermore under some of the experimental conditions it is unlikely that much acetic acid is produced by the action of micro-organisms on the pulp. This is supported by observing the pH changes in the cotyledons. Under normal conditions of fermentation, whether untreated beans or frozen and thawed beans are used, due presumably to the penetration of acetic acid, the pH of the cotyledons falls by 1.5 or more units whereas with frozen, thawed and sun-dried beans the pH falls by not more than 0.4 unit.

It has been thought that the formation and penetration of acetic acid into the cotyledon of the bean during fermentation was important for the production of good quality cocoa. It now appears that the question of the importance and function of acetic acid in flavour development with Amelonado cocoa requires to be re-examined.

LARGE-SCALE FERMENTATION OF AMELONADO COCOA

(H. W. S. Allison and R. H. Kenten)

Data accumulated over the past three seasons on heap and tray fermentations of Amelonado cocoa is being examined statistically. The overall weighted mean conversion ratio (dry/wet weight) for 492 heap fermentations was 44.4 per cent. and the standard deviation 2.6 per cent. With heap fermentations this ratio varies with the season. It is at its lowest in June to July (weighted means 38.7–39.1 per cent.) and rises to a maximum in October to February (weighted means 45.3–46.7 per cent.). A similar pattern is observed with the rate of temperature increase in tray and heap fermentations which with the minor crop is appreciably slower than that found with the main crop.

Further samples of Amelonado cocoa from stacked tray fermentations of three, four, five, and six day duration have been factory processed and assessed by the C.S.A.C. They agreed that all the samples were satisfactory as West African cocoa and that the varying periods of fermentation had procuced no significant differences between the samples.

This year drying in the trays in a two-inch layer was not entirely satisfactory. During wet weather external mould growth was encouraged and this led to the development of internal mould in some batches. However, tray drying in a one-inch layer was perfectly satisfactory throughout the season. Although no quality assessments are yet available cocoa with a satisfactory internal appearance has been produced by fermenting in $\frac{1}{3}$ and $\frac{1}{4}$ trays and spreading over

the whole tray for drying. Experiments are being made with larger trays in order to determine the optimum depth and size.

STATISTICS

(C. de Jonge)

This year much help has been given to the Scientific Divisions in the design and analysis of experiments. Among the various analyses carried out, special mention may be made of the work on the association of Calonectria Die back with virus-infection (see p.74).

Since the institution of the Plots Committee, all designs for field experiments are examined by the Statistician, and on occasion modifications in design have been suggested which have led to better use of the available land. The method adopted consists of studying the simultaneous F requirements of alternative orthogonal designs with allowance for the age of the cocoa. In some cases, split-plot degrees of freedom have been created by inside replication of the recording system. Tests against these reflect short-range geographical variation.

The contruction of an air-conditioned computing room has been planned to centralize the electrical equipment.

IBADAN STATION

VIRUS RESEARCH

TRANSMISSION OF NIGERIAN COCOA VIRUSES (C. K. H. Martini)

A study of the insect transmission of Nigerian isolates of cocoa swollen shoot virus (CSSV) has been completed. Most of the results obtained by Posnette and co-workers (Posnette and Strickland, *Ann. appl. Biol.*, **35**, 53-63, 1948; Posnette and Robertson, *Ann. appl. Biol.*, **37**, 363-377, 1950) in Ghana were confirmed. Their view, however, that CSSV is more readily transmitted by insects that are starved prior to feeding on infected plants, and could therefore be grouped with the aphid-transmitted, non-persistent viruses, is not shared. In the relevant experiments of Posnette and Robertson (*loc. cit.*) a constant preliminary starvation period of twelve hours was compared with no starvation period, and infection feeding times were varied. These experiments tested the effect of increased infection feeding times rather than of preliminary starvation. No increased transmission was observed in experiments with Nigerian isolates in which infection feeding time was constant and starvation period varied.

The short period for which feeding mealybugs retain CSSV made

it seem likely that the virus adheres to the stylets only and further evidence has been obtained on this point. Using Bradley's method (*Virology*, **8**, 308-318, 1959) of comparing the transmissions caused by insects from infected plants after keeping them on glass and filter paper, respectively, it was found that insects lose infectivity more rapidly on filter paper.

Other experiments indicate that the amount of virus adhering to the stylets varies with the time spent on infected plants. The infectivity of insects that have grown up on infected plants and are starved on glass remains unchanged for seventeen hours; twenty-four hours after leaving the plant it reduced to about 50 per cent., and lost entirely after thirty to forty hours. The infectivity of insects that have spent only four hours on infected plants is lost entirely after seventeen hours on glass.

Aphis gossypii Glover, has also been tested as a vector of CSSV and the isolates from Ajia and Offa-Igbo 159 have been transmitted at a rate of 12 per cent. when fifty insects were fed on soft leaves of the second flush of seedlings infected at the bean stage and subsequently on test beans. No transmissions were obtained with the isolates from Alaparun, Koroboto and Balogun.

Further attempts have been made to establish the vector of cocoa necrosis virus (CNV). In further tests with the mealybug species *Ferrisiana virgata* (Ckll.) and *Planococcoides njalensis* (Laing), cocoa seedlings nine- to twelve-month old, cut back to a height of about eight inches were used as test plants as such plants had proved to be the most suitable indicators in graft experiments. Other insect species tested were: *Sahlbergella singularis* Haglund, *A. gossypii* and smaller numbers of several unidentified insects from the outbreak of CNV at Omi-Aboderin. No transmissions were obtained.

In co-operation with Dr F. E. Caveness (I.D.S.—Specialist Section, Ministry of Agriculture and Natural Resources, Western Nigeria) three species of migratory soil nematodes which occur on cocoa at Omi-Aboderin are being tested as possible vectors of CNV.

PARASITIC PLANTS (T. W. Tinsley)

Cuscuta campestris Yuncker, *C. subinclusa* Dur. et Hilg. (Convolvulaceae) and *Cassytha filiformis*, L. (Lauraceae) have been used in attempts to transmit CSSV (Egbeda, Ikire, Abuku and Asejire isolates) and Cocoa mottle leaf virus (CMLV) from infected cocoa to healthy seedlings. *C. filiformis* will feed directly on cocoa whereas the *Cuscuta*s pp. require a secondary host (*Desmodium* sp.) before active growth takes place. *Vinca* and *Petunia* were used as intermediate hosts in some experiments. No transmissions were recorded.

EXTRACTION OF COCOA SWOLLEN SHOOT VIRUS

(C. K. H. Martini and T. W. Tinsley)

Preliminary attempts have been made to extract CSSV from infected cocoa seedlings and *Adansonia digitata* L. Samples were examined in the electron microscope by Mr H. L. Nixon at Rothamsted Experimental Station and the virus appears to be a short, rigid rod of about 220 mμ length.

THE SPREAD OF COCOA SWOLLEN SHOOT VIRUS (J. M. Thresh)

In a recent paper, van der Plank (*In: Plant Pathology: problems and progress 1908-1958, Univ. of Wisconsin Press, Madison 1959*, pp. 566-573) stressed the slow rate at which systemic diseases spread in tree crops, compared with the spread of diseases (particularly those causing local infections) in annuals. The spread of swollen shoot disease in West African cocoa is a particularly good example. It is also a typical 'crowd' disease, i.e. one which does not spread far in any considerable amount (van der Plank, *Emp. J. exp. Agric.*, **63,** 134, 1948). This is indicated by the following evidence:

1. That most of the cocoa in Ghana is still free of virus even though infection has been widespread for many years and was first suspected as long ago as 1922.
2. The slow spread of virus from the abandoned areas of mass infection in Nigeria.
3. The success of eradication measures in controlling spread.
4. The slow rate at which virus spreads in observation plots, and the occurrence of most new infections alongside trees already showing symptoms.
5. The steep gradients of latent and missed infections revealed by coppicing the apparently healthy trees around swollen shoot outbreaks.
6. The slow rate at which virus spreads into newly planted cocoa, particularly farms which are not established alongside existing infections.
7. The localized distribution of many virus strains, which are often restricted to certain areas.

The factors limiting spread have not been elucidated, but the small numbers of mealybugs, their scattered distribution and limited activity are probably the most important. However, other factors involving both virus and host are also concerned. For example, virus

may not become fully systemic in mature trees until some months after inoculation and symptoms may fail to appear for more than a year. Even then, virus is not uniformly available to feeding mealybugs, but seems to decline after the initial acute phase of infection has passed. Virus availability is also correlated with the flushing behaviour of the trees and is probably low during the dry season and at the height of the rains when the trees are making little new growth. The spacing, age and condition of the trees are yet other factors influencing spread and many trees are so heavily affected by the capsids and fungi causing dieback that they are no longer in contact with their neighbours.

Under these circumstances it is hardly surprising that cocoa swollen shoot disease spreads slowly and that trees may remain symptomless for many months, even though they are in contact with infected trees. This situation has been reported at various naturally occurring outbreaks in Nigeria and also in farms which were infected with virus in recent inoculation experiments in Nigeria. These experiments have demonstrated the difficulty of starting spread by artificial inoculation. Single trees were inoculated by grafts at localities in 1958 and the inoculated trees showed symptoms after a few months. However, spread has been observed at only one locality and elsewhere the contact trees have remained symptomless. This may be due to the low probability of a single randomly selected tree supporting an active mealybug population. For example, 62 per cent. of the trees examined at Tafo in Ghana in the season 1947–48 were found with less than twenty-five mealybugs and 45 per cent. had none at all (Strickland, *Bull. ent. Res.*, **42**, 65-103, 1951). The populations in Nigeria are similar and it is probable that many of the outbreaks which are started naturally by windborne mealybugs either fail to spread, or do so very slowly.

THE EFFECT OF VIRUS ON YIELD AT KOROBOTO (J. M. Thresh)

The outbreak of swollen shoot disease in peasant-owned cocoa at Koroboto has been under routine observation since 1953 and since that date the number of infected trees has increased from 49 to 606 in August 1959. Individual tree yield records have been taken since August 1954 and capsids have been virtually eliminated since *gamma*-BHC spraying started in March 1956.

The interpretation of the yield records is difficult, because the condition of the trees is only partly due to the length of time they have been infected with virus. Nevertheless, there were significant negative correlations between the number of months the trees had been showing symptoms and the yield in pods per tree for the crop

seasons 1954–55 and 1955–56. Yields in each season were also correlated with girth and this relationship was used to obtain partial correlations between yield and duration of infection (Table 28).

TABLE 28

Correlations between yield, girth and duration of infection at Koroboto swollen shoot observation plot

Crop season	*Simple correlation yield and virus*	*Simple correlation yield and girth*	*Simple correlation girth and virus*	*Partial correlation yield and virus eliminating girth*	*Number of infected trees*
1954–1955*	+0.200	+0.229	+0.076	+0.188	157
1955–1956*	+0.321	+0.323	−0.019	+0.346	274
1956–1957†	+0.187	+0.309	−0.045	+0.212	386
1957–1958†	−0.028	+0.381	−0.176	+0.043	524
1958–1959†	−0.138	+0.415	−0.180	−0.070	606

* Before capsids were controlled.
† Capsids controlled by monthly applications of *gamma*-B.H.C. using a Motoblo.

The data clearly indicate a progressive deterioration of the infected trees in the absence of capsid control measures. This relationship became less marked for the crop season in which capsids were controlled and has since disappeared. Indeed, in the 1958–59 season there was a slight tendency for the oldest infections to outyield the most recent.

This analysis provides further evidence of the importance of capsids as a factor influencing the effects of swollen shoot virus. The most virulent strains drastically decrease the number, area and longevity of the leaves, particularly at the acute stage of infection when new growth is checked or stunted. This seems to increase both the incidence and spread of dieback (Kay, unpublished) and decreases the ability of the tree to compensate for this loss of canopy by making extensive new growth. Under these circumstances the trees deteriorate and may become worthless as grasses and weeds invade the farm to compete for nutrients and soil water.

This working hypothesis accounts for the observed interaction between virus and capsids and is now being investigated by further spraying trials on naturally occurring outbreaks and by formal field experiments in which inoculated trees are being pruned to simulate capsid damage. The behaviour of the fungus *Calonectria rigidiuscula* Berk. and Br. (Sacc.) in invading capsid lesions and causing dieback in virus inoculated and healthy trees is also being investigated by Mr Kay.

TOLERANCE TO SWOLLEN SHOOT DISEASE

(J. M. Thresh and J. F. Longworth)

Insectary experiments

Numerous tests have been made to determine the reaction of different cocoa populations to infection with swollen shoot virus. Infected rootstocks were not always available and the usual technique was to bud the variety under test on to healthy T(N) 38 seedlings which were later graft-infected with the virulent virus isolate from Egbeda. The most striking feature of the results has been the extreme susceptibility of the Amelonado budlings, which rapidly showed conspicuous swellings and leaf symptoms. These were particularly severe at the initial acute stage of infection, when there was crinkling and discoloration of the young leaves which sometimes abscissed.

The most susceptible of the Trinitario clones behaved like Amelonado, with crinkling and abscission of the leaves, severe chlorosis and swellings. However, most clones produced less severe leaf symptoms, although these were sometimes associated with large swellings. The leaf symptoms caused by the E1 clones C23 and C26 were particularly mild and the swellings are slow to appear. This suggests that the Trinitario group is a potential source of tolerance and further selection may reveal outstanding clones for hybridizing with tolerant Amazons.

The reaction of the different Amazon populations has been very variable and only tentative conclusions can be drawn from the results to date. Nevertheless, all the Scavina hybrids tested produced conspicuous leaf symptoms and in some instances swellings and there was no evidence of any marked tolerance. By comparison, the Nanay × Iquitos clones gave inconspicuous and limited leaf symptoms, not usually associated with large swellings. There is evidence for differences in susceptibility within the Nanay and Nanay × Iquitos types; T85 (Na34 × IMC60) seedlings have proved outstandingly tolerant in two tests in which they produced only very mild, transient leaf symptoms and no swellings.

The Parinari and Parinari × Nanay clones have given quite distinct necrotic symptoms not reported previously in Ghana or Nigeria. These symptoms appeared first as chlorotic flecks along the third and fourth order veins which later become necrotic. Usually the necrosis spread into the main veins until the leaves and petioles collapsed and abscissed, though in some instances the leaves hardened and were retained. The necrosis sometimes spread to the growing point and growth was then checked. The significance of the necrosis symptoms and the associated effects on growth and yield

are being evaluated. It is already clear that these symptoms are not confined to young, particularly sensitive material as used in the laboratory tests, because young trees at Koroboto infected twenty months after planting have been affected in the same way.

The apparently severe effect of virus on the Parinari × Nanay clones is unfortunate. Further work will be necessary to select Amazon parents which can be crossed with Amelonado or Trinitario varieties to give acceptable hybrids with a high degree of tolerance to virus. It is hoped that such crosses will bè produced during the coming season, and the progeny will be tested at the earliest opportunity.

KOROBOTO SEEDLINGS EXPERIMENTS (J. F. Longworth)

The purpose and layout of these experiments have been described (*Rep. W. Afr. Cocoa Res. Inst.*, 1958–59, pp. 79-80). The first experiment consisted of a factorial layout of irrigation and none versus fertilizer and none, with main plots split for healthy controls and mild and severe virus inoculation. The area has been heavily mulched and was shaded for the first dry season; these two factors were apparently sufficient to mask any effect of irrigation. The reduction in growth due to virus has been maintained (see Table 29).

TABLE 29

Mean girth (cm.) of seedlings in virus treatments (December 1959)

Control	*Mild virus*	*Severe virus*
4.02	3.78	3.14

An interaction between virus infection and the dieback fungus *C. rigidiuscula* was observed when lengths of the lesions caused by the fungus in inoculated plants were measured when the first experiment was thinned in July (see Table 30).

TABLE 30

Mean length (cm.) of Calonectria *lesion in virus treatments (July 1959)*

Control	*Mild virus*	*Severe virus*
29.9	31.0	38.8

Extension of the lesions was significantly greater ($P=0.1$) in virus infected plants. A similar trend in *Calonectria* lesion lengths in the second experiment did not prove significant.

The second experiment consisted of similar virus treatments split upon the plots of a 2^2 factorial layout of shade and none versus fertilizer and none. Again the experiment was heavily mulched and this virtually eliminated losses during the first dry season. The shade treatment promoted growth during this period, but with the onset of the rains the situation was reversed, and growth was greater in exposed plots.

Virus infection further reduced growth, particularly in exposed plots (see Table 31).

TABLE 31

Mean girth (cm.) of seedlings in virus treatments under shade and without shade (December 1959)

	Control	*Mild virus*	*Severe virus*
No shade	4.01	3.83	2.78
Heavy shade ..	3.66	3.53	2.96

This reduction was relatively less under shade; the interaction being significant (P=0.1, degrees of freedom for error=40).

Measurements of total length and number of lateral roots were made on plants removed during thinning, and in both experiments fertilizer applications significantly reduced root length and number, though this effect was not accompanied by a general reduction in size of manured plants. In both experiments lateral root length and number were significantly reduced by virus infection (P=0.1). Moreover the reduction caused by virus infection was relatively smaller under shade than in exposed plots in the second experiment (see Table 32).

TABLE 32

Mean total root length (cm.) of seedlings in virus treatments with and without shade (June 1959)

	Control	*Mild virus*	*Severe virus*
No shade	221.8	187.5	155.7
Heavy shade ..	172.0	178.9	167.8

This interaction was significant (P=0.1), even though the reduction in total root length in shaded plants was not.

These experiments indicate that virus-infected cocoa is in a delicate balance with the environment, and is particularly sensitive

to changes in light intensity. Capsid infestation of cocoa infected with virus permits the entry of *Calonectria* to which such trees have been shown to be particularly susceptible, and also leads to changes in the environment which are deleterious to trees whose growth is suboptimal. The regenerative capacity of an infected tree is reduced (Voelcker and West, *Trop. Agriculture, Trin., 19*, 83. 1942) and is further affected by the spread of *Calonectria.*

AGRONOMY

NURSERY EXPERIMENTS (J. F. Longworth)

The experiment described in the previous Annual Report consisted of three shade treatments, heavy and light palm-frond shade, and no shade. There was a factorial arrangement of fertilizer application and spacing of the 'whalehide' pots under each shade treatment. At first, growth was greatest under light shade and without shade the seedlings appeared stunted with some chlorosis and crinkling of the flush leaves. However, after the onset of the rains the plants without shade made good growth. The treatment differences at transplanting are shown in Table 33.

TABLE 33

Total growth (m.) in the three shade treatments at planting (May 1959)

Heavy shade	*Light shade*	*No shade*
196.2	270.2	266.6

As a check of growth was noted after the first two fertilizer applications, the treatment was discontinued. The seedlings were planted in the field at Araromi-Aperin in the form of an establishment trial with six replications of the twelve treatment combinations. The poor soil and severe dry season resulted in incomplete establishment of the temporary banana shade, and an extensive weed growth. Consequently, establishment of the seedlings has not been good, and was further influenced by a particularly severe dry season including three months without rain.

Such conditions are common in Nigeria where planting is attempted on a large scale following clear-felling, and combine to make establishment hazardous.

In Table 34 it is clear that although the shade treatment in the nursery has had little effect on subsequent survival in the field, the effects on growth of the surviving plants has been striking, and in

TABLE 34

(a) Total growth (m.) and (b) establishment percentages in the shade treatments in the field (March 1960)

	Heavy shade	*Light shade*	*No shade*
(*a*)	218.8	257.0	260.9
(*b*)	64.24	60.69	58.86

view of the excellent growth made in the light and no shade treatments a further trial was begun in Agodi nursery in October 1959. Similar shade and spacing treatments were used except that the light shade has been gradually reduced until March, when the shade was completely removed. Different watering regimes were applied:

watering on alternate days (W1)
watering twice each week (W2)
watering once each week (W3)

The effects of the shade treatments on early growth in the nursery were similar to those in the previous experiment (Table 35).

TABLE 35

Growth (cm.) in the second nursery experiment (February 1960)

	Heavy shade	*Light shade*	*No shade*	*Totals*
W1 ..	2,894	3,628	2,671	9,193
W2 ..	2,742	2,831	1,796	7,369
W3 ..	2,300	2,428	1,264	5,992
Totals ..	7,936	8,887	5,731	

Seedlings under light shade with frequent watering have made prolific growth and it is likely that at planting time, in May, they will be unsuitably large, as the tap root will be damaged when moving the pots. Even in this treatment, growth may be limited to some extent by the water supply, and more vigorous seedlings might be obtained with more frequent watering. Treatment W3 is obviously inferior particularly on seedlings without shade.

The first experiment was planted in the nursery late in the main-crop period (December) whereas the second was planted earlier (October). These trials have shown that with suitable adjustment of shade and water supply extremely vigorous seedlings can be produced. Early planted seedlings under light shade may be too large to transplant successfully and it is possible therefore that the management adopted in the nursery must be adjusted according to the time of planting of seed.

STUDIES ON 'DIEBACK' OF COCOA

(D. Kay)

In Nigeria, two forms of dieback occur and are caused by fungal infections and physiological disorders respectively. Externally they appear similar, but dieback caused by *Calonectria rigidiuscula* (Berk. and Br.) Sacc. shows a distinct intermediate dark zone between the dead and living tissue. The second type of dieback does not show this distinct zonation and occurs frequently in the field during the dry season, when environmental factors limit the growth of the tree, but is virtually absent during the wet season, when conditions for growth are good. The resulting dead wood may subsequently be colonized by *C. rigidiuscula* and lead to fungal dieback.

Although two fungi have been regularly isolated from dieback, only *C. rigidiuscula* is considered to be of importance. This fungus can establish itself and spread in cocoa stems and when inoculated into twigs can cause dieback. The perithecial stage of *C. rigidiuscula*, and the micro- and macro-spore stages of the imperfect form of this fungus, *Fusarium decemcellulare* (Brick), have been cultured in the laboratory. The micro- and macro-spores readily infect cocoa stems, but no spread of the fungus at an inoculation point has been obtained in experiments using ascospores only. The fungus is not a primary parasite, but gains entry through wounds and via existing dead wood.

Much of the fungal infection in Nigeria follows mirid feeding damage. Infected areas may be occluded or may spread to cause dieback, the latter occurring more commonly from terminal infections. Although there is no experimental evidence that the fungus, once occluded, can cause dieback or influence the spread of dieback in the tree, it has frequently been observed during the dry season that dieback arises near occluded mirid damage. It has been shown experimentally that the water conducting tissue in the stem is destroyed in the region of an occluded lesion and it is suggested that during times of water stress this may be of great importance in the formation of dieback.

A record of the number of twigs that died after they have been inoculated with *C. rigidiuscula* showed that vigorous twigs with numerous leaves and having green/brown bark were less liable to dieback to the point of inoculation than were less vigorous twigs possessing few or no leaves and having brown/black bark.

In a plot of healthy bearing cocoa, twigs were inoculated at monthly intervals for one year and records were kept of the number which subsequently died.

Dieback spread was greater from inoculations in twigs on trees infected with the cocoa swollen shoot virus than in twigs on similar

virus-free trees. In Nigeria, an average of 32.6 per cent. of the twigs previously infected with the virus died compared with an average of 18.2 per cent. in virus-free trees, whereas in Ghana, an average of 38 per cent. of twigs previously infected with virus died, compared with 25 per cent. of the virus-free twigs. This does not give an absolute comparison of the effect of the virus or dieback, because twigs of equal diameter were selected on the virus infected and virus-free trees which did not allow for differences in growth caused by virus infection. A further trial is in progress in which twigs of uniform diameter were selected and marked before infection with the virus, and later, when virus leaf symptoms had been observed, they were inoculated with the fungus at a fixed distance above the marking. In an experiment in Ghana the number of twigs which died was found to vary with the type of virus present in the tree. Deaths were most numerous on trees infected with a severe New Juaben isolate of the CSSV and least when infected with a mild New Juaben isolate.

The linear spread of dieback after inoculation was measured and was found to be much greater on virus-infected trees in Ghana than in Nigeria. Spread was greatest on the trees infected with the severe isolates of the cocoa swollen shoot virus.

Fungal dieback is not confined to trees previously weakened by other diseases. It is frequently found on high yielding trees with a full canopy, but as such trees regenerate freely, the losses from dieback are of little importance. Mirids, a major factor influencing the severity of dieback, are most numerous at the beginning of the dry season at a time when the spread of existing dieback is at its greatest. Furthermore, growth and regeneration even of healthy trees is slow at this time, and the impact of dieback can therefore be more serious. In some localities the trees may begin to recover from dieback each rainy season and then deteriorate again in the following dry season. Control of mirids by spraying is normally sufficient to permit complete regeneration.

The most important aspect of dieback, once mirids have been controlled, is the interaction with cocoa swollen shoot virus. It is believed that trees in Nigeria succumb to dieback most readily during the acute early stage of virus infection when new dieback may arise from occluded, infected lesions that were present in the trees before spraying against mirids commenced.

In cocoa that has been sprayed against mirids the formation of new dieback foci can be controlled by reducing the reservoir of the fungus in the plot by pruning off the dead wood and then spraying with fungicides. The spread of existing dieback can be reduced by watering during drier periods.

Experiments are in progress to test the variation in the suscep-

tibility of selected clones to infection with *C. rigidiuscula*. No clones have been found to be very resistant to infection, but some are more susceptible than others. In general, the more vigorously growing Amazon varieties are less susceptible than the Trinitario or Amelonado varieties, but within a variety, the tree to tree variation in susceptibility is quite high. It appears that the more vigorous the tree, the more resistant it is to dieback. In areas where it may be anticipated that dieback could be serious, e.g. in areas with a pronounced dry season or where trees are subject to infection with cocoa swollen shoot virus, it might be advisable to plant vigorous varieties that will resist dieback, even though they may be less suitable in other respects such as yield. Further, it is suggested that varieties selected for resistance to virus infection should, at the same time, be tested for resistance to dieback.

FUNGICIDES RESEARCH

BLACK-POD CONTROL (E. C. Hislop and P. O. Park)

Laboratory studies

The laboratory technique for assessing the effectiveness of fungicides in protecting individual pods against infection by *Phytophthora palmivora* (Butl.), first reported in the Annual Report 1959–60, has been further refined.

The laboratory sprayer has been modified to give a more constant emission rate and the position of the spray nozzle can be reliably set against a permanent scale. Air is now drawn from the back of the apparatus by a suction pump and it is hoped that this will reduce turbulence inside the chamber permitting a more even deposition of fungicide. A further modification is the erection of a continuously agitated spray container with simplified controls, leading to the spray nozzle.

During the last dry season the chemical technique for the estimation of residues on pods has been improved. The distribution of deposits on pods sprayed in the modified laboratory sprayer is being examined by a stripping technique involving the use of a cellulose acetate film and a 5 per cent. acetone solution of cellulose acetate. By this technique it is possible to remove the fungicide deposit from selected areas of the pod.

The infection of detached pods by zoospores of *P. palmivora* has been re-examined during the past year. The strength of the zoospore suspension has been standardized at 200,000 per ml. and as a result, the number of lesions developing on untreated pods is now more

constant. Previously all artificial infections were made with zoospores obtained from pods naturally infected in the field and it was not possible to prove conclusively that only zoospores of *P. palmivora* were causing the lesions, because the natural infections always contained contaminants. Attempts to produce a pure zoospore suspension from artificially inoculated sterile pods, kept under sterile conditions, were often unsuccessful because of contamination. However, all the evidence indicated that only zoospores were causing lesions. This fact has recently been confirmed by the use of zoospores obtained from artificial cultures.

It has been found possible to grow and perpetuate a local isolate of *P. palmivora* on a cassava-concoction agar containing the strainings of 200 gm. of boiled cassava pieces, 20 gm. dextrose and 20 gm. agar per litre. Plates inoculated centrally are covered in about seven days at 25°C. and there is a marked zonation of sporangial production.

Inoculation of pods with zoospores produced from sporangia grown in culture has confirmed that three distinct types of lesion may result.

Type (A) is a small usually discrete water-soaked spot which often fails to develop and is considered to be a hypersensitive reaction.

Type (B) is a rapidly expanding lesion with a mottle or reticulate appearance and indefinite outline.

Type (C) is the typical, rapidly enlarging, brown lesion with a more or less distinct margin.

B type lesions may later develop to produce C type lesions.

All pods used for laboratory fungicide testing are obtained from one isolated area of cocoa described simply as West African Amelonado and frequently A and B or A and C type lesions occur on the same pod. For purposes of fungicide testing all lesions larger than 2 mm. are counted and, since each test is well replicated, no record is made of the type of lesion.

During the main cocoa season from June to December 1959 the following fungicides were compared in various series for their effectiveness in preventing the infection of detached pods by *P. palmivora* using standard laboratory Bordeaux mixture (*Phytopathology.*, **33**, 633, 1943) as a comparative standard.

Cuprous Oxide (50 per cent. Cu) as Perenox, YF5616 and Caocobre Sandoz.

Copper oxychloride (50 per cent. Cu) as Kopapod, Cocoa Spray, Coprantol and Coppesan.

Mixed fungicides containing:

Formulation (A) 33.5 per cent. Cu (as copper oxychloride) + 32 per cent. ziram.

(B) 37.5 per cent. Cu (as COC) +15 per cent. Zineb.

(C) 50 per cent. Cu (as COC) +0.6 per cent. Hg (as phenyl mercury chloride).

(D) 50 per cent. Cu (as COC) +? per cent. Hg.

In typical experiments the fixed copper fungicides were applied at 0.15 per cent. w/v and the standard laboratory Bordeaux mixture at 0.075 per cent. Cu, or 0.10 per cent. w/v and 0.05 per cent. Cu respectively.

The cuprous oxide formulations were not significantly different from one another but standard laboratory Bordeaux mixture was significantly (P=0.05) superior to two of them in preventing infection of pods by *P. palmivora*. The copper oxychloride formulations were consistently inferior to the cuprous oxides in terms of pod protection. Of the mixed fungicide formulations the copper/mercury mixtures appear to be better than the copper/organic fungicide mixtures.

During the dry season when pods were not readily available attempts were made to examine the toxicity of fungicides in the laboratory by the slide germination technique (*Phytopathology.*, **33**, 633, 1943). In particular it was hoped that this technique would elucidate the differences in efficacy of cuprous oxide and copper oxychloride. A settling tower (McCallan, S. E. A. and Wilcoxon, F., *Contr. Boyce Thompson Inst.*, **12**, 309, 1940) was built and, using a de Vilbiss No. 15 nozzle, it was calibrated using Kiton red dye. The mean deposit of dye per glass slide (3 in. × 1 in.) is 98 μgm. on batches of twelve slides with replicate mean deposits within ±3 per cent. The actual deposit of copper from standard laboratory Bordeaux mixture sprayed in the tower and determined chemically, agreed very closely with the theoretical values based on the dye calibrations. When however, the deposit of other fungicides were determined chemically the agreement between theoretical and actual deposit values were not always good. This was found to be due to the incomplete solution of the deposit and when the concentration of Teepol in the acid washing solution was increased from 0.1 per cent. to 0.5 per cent. the differences were corrected.

The results of slide germinations tests using the zoospores of *P. palmivora* as the test organism were very variable and unsatisfactory. In an attempt to trace some of the variability, the settling tower was abandoned in favour of the test-tube dilution technique for use with the slide germination method of evaluating protectant

fungicides (*Phytopathology.*, **37**, 354, 1947). This is the most precise technique for water-soluble materials, such as copper sulphate, which has been used extensively. Until this time it had been assumed that since the zoospores were all liberated within a period of twenty minutes the age of the culture from which they were produced was not important. This, however, has been shown not to be so. Zoospores produced from eight-day-old cultures were more sensitive to copper sulphate than zoospores from twelve-day-old cultures. It also seems that the line obtained by plotting the concentration or dose against the percentage inhibition of spore germination on logarithmic probability paper is not straight, but concave. From these observations it became clear that zoospores are very sensitive to copper, as would be expected from their small size, and that a germination record of an 'all-or-none' nature was not satisfactory. For example the percentage germination of one batch of zoospores in a copper sulphate solution containing 0.3 p.p.m. copper was very nearly the same as zoospores in 0.1 p.p.m. copper solution but the mean length of the germ tubes in the weaker solution was about five times more than that in the stronger solution.

Considering the difficulties encountered in comparing water-soluble fungicides it is realized that the slide germination technique is not promising for examining the toxicity of fungicides to the zoospores of *P. palmivora*. The critical examination of fungicides in an attempt to determine their LD50 values has therefore been abandoned in favour of a less critical examination designed solely to elucidate some of the findings of the laboratory screening.

Field studies

The efficiency of four fungicides in controlling 'black-pod' in the field was examined in a trial laid down at Owena. Two formulations new to Nigeria, both containing 50 per cent. copper as cuprous oxide, were compared with an already accepted cuprous oxide formulation and with Carbide Bordeaux mixture.

The four treatments were randomized on twenty tree plots in each of ten blocks. The cuprous oxide formulations were applied at 0.4 per cent. w/v and the Carbide Bordeaux at 1 per cent.; i.e. 0.25 per cent. copper. The Carbide Bordeaux was regarded as a control. The fungicides were applied three-weekly with Four Oaks pressurized knapsack sprayers fitted with Four Oaks No. 51 nozzles at a pressure of 45 lb./sq. in. The pods were sprayed to run-off, the first application being made on 21/5/59 and the last of nine sprayings on 6/11/59. The pods were harvested and recorded tree by tree one day before each spraying date.

Black pods were present on all the treatments from the beginning of July. The percentage infection for July and August was high and variable because very few ripe pods were being harvested while black pods were removed as they developed. During September, October and November the main crop ripened and the black pod percentages recorded during this period were more representative of the actual incidence in the field. Eighty-seven per cent. of the total pods recorded throughout the period of the trial came from the last four harvests. During this period the variation was minimal and therefore the analysis summarized below relates to this period only.

In Table 36 the present accepted standard cuprous oxide is designated formulation A. The formulations designated B and C are the ones under examination.

TABLE 36

Total pods and black pods for the four main harvests

Treatment	*Formulation A*	*Formulation B*	*Formulation C*	*Carbide Bordeaux*
Total pods ..	1,541	1,684	1,640	2,105
Black pods ..	326	388	336	633
Black pod %	20.2	23.0	20.4	30.0

An analysis of variance in the data summarized above indicated that Carbide Bordeaux mixture was significantly inferior to the three cuprous oxide formulations at the 5 per cent. level. However, an analysis of covariance demonstrated a significant (1 per cent. level) correlation between black pod numbers and total pods produced per plot (Thorold, C. A., *J. hort. Sci.*, **31**, 149, 1956). An anlysis of variance on adjusted black pod figures obtained after correction for this correlation showed that the differences between treatments were no longer significant.

It is encouraging to note that the same result was obtained in the less laborious and very much less expensive laboratory tests on these materials.

A GALL DISEASE OF COCOA IN NIGERIA

(J. F. Longworth)

Several trees were found with galls on flowering cushions in the plot of I.C.S. cocoa at Moor Plantation in 1958–59. Most of the galls were on the trunks, and such trees were pollarded below the gall. When affected cushions were found on lateral branches, the galls were excised. Both treatments have apparently freed the trees from infection, suggesting that a satisfactory control measure could be developed by pruning away affected portions of the tree.

Burridge, J. C. and Cunningham, R. K. (1960): 'Cacao Yield Maps and Soil Fertility in Ghana'. *Emp. J. exp. Agric.*, *28*, pp. 327-334.

A technique is described for producing cacao yield contour maps. Yields on a soil developed under moist semi-deciduous forest in Ghana were shown to be correlated with the chemical analysis of the 0-6 in. layer of the soil. The yield pattern revealed by these contours indicated a local high variability in the fertility of the surface horizon of the soil.

Cunningham, R. K. and Burridge, J. C. (1959): 'The Effect of the Yield Variability of Amelonado Cocoa on the Design of Fertilizer Field Experiments in Ghana'. *J. hort. Sci.*, **34**, pp. 229–237.

Yields of Amelonado cocoa grown in Ghana have been analysed in an attempt to assess the minimum requirements for the design of fertilizer field experiments capable of detecting 20 per cent. yield responses at the $P=0.05$ level of significance. Normal distributions of yield data were obtained by grouping trees, by logarithmic transformation or by a combination of both methods. For single season experiments, coefficients of variability in the range 30 to 60 per cent. made replications too high to be practicable. Adjusting data from paired seasons reduced replication to about twelve, which was just sufficiently low to make accurate experiments possible. A circular plot technique for use in random cocoa is described.

Cunningham, R. K. and Burridge, J. C. (1960): 'The Growth of Cacao (*Theobroma cacao*) With and Without Shade'. *Ann. Bot.*, N.S., *24*, pp. 458-462.

Evidence is presented that young plants of cacao can tolerate high light intensities if provided with adequate water and nutrient supplies.

Cunningham, R. K. and Smith, R. W. (1961): 'Comparison of Soil Covers during Cocoa Establishment on Clear-felled Land'. *Trop. Agriculture, Trin.*, *38*, pp. 13-22.

The use of covers for soil protection during the establishment of cocoa on clear-felled land has been studied. Five cover crops and one mulch have been tested. The ability of these covers to protect the soil, maintain a good water relationship, prevent high soil temperatures and establish a good nutrient balance has been investigated. Cocoa has been planted and its growth in the various treatments has been assessed. It has been shown that a protective cover is essential for exposed forest soil and

that selected covers are better than natural regeneration. However, all those used in this work had some disadvantage and a wider selection of plants must be tested before a final choice is made.

Entwistle, P. F., Johnson, C. G. and Dunn, E. (1959): 'New pests of Cocoa (*Theobroma cacao* L.) in Ghana following applications of insecticides'. *Nature*, **184**, p. 2040.

Holden, M. (1959): 'Processing of Raw Cocoa'. III—'Enzymic Aspects of Cocoa Fermentation'. *J. Sci. Fd. Agric.*, **10**, pp. 691–700.

The changes in the levels of a number of oxidizing and carbohydrate-splitting enzymes of Amelonado cocoa bean cotyledons during both large- and small-scale fermentations were determined, on samples of beans taken after various periods of fermentation from the top and centre of heaps of different sizes. Inactivation of enzymes took place sooner in the top layer, where the temperature rise was more rapid, than at the centre. Enzyme levels started to diminish during the period when the beans were dying and continued until, after three days' fermentation, little or no activity was detectable. The results suggest that prolonging fermentation for several days after the beans are dead is neither necessary nor desirable.

Kenten, R. H. and Powell, B. D. (1960): 'Production of Heat during Fermentation of Cocoa Beans'. *J. Sc. Fd. Agric.*, **11**, pp. 396–400.

The heat produced during the fermentation of cocoa beans could arise from the action of the bean enzymes as well as from the activities of micro-organisms on the pulp which surrounds the beans. Experiments to ascertain the relative importance of each of these cources have shown that most of the heat produced arises from the activity of micro-organisms in the pulp.

Thresh, J. M. and Lister, R. M. (1960): 'Coppicing Experiments on the Spread and Control of Cacao Swollen Shoot Disease in Nigeria'. *Ann. appl. Biol.*, **48**, pp. 65–74.

A coppicing technique was used to determine the incidence and distribution of latent and unrecognized infection around naturally occurring outbreaks of cacao swollen shoot virus disease in Western Nigeria. All the apparently healthy trees within thirty yards of eighty outbreaks of various sizes were coppiced and most of the infected stumps which regenerated showed symptoms within a year.

The distribution of the infected stumps around thirty-five outbreaks studied in detail is expressed by the equation $\log_{10}$

$I = a + bx$. I is the estimated intensity of infection in the coppiced stumps at distance x from the nearest infected tree removed at the time of coppicing. The constant a determines the height of the peak of the infection gradient and increases with outbreak size, whereas the slope of the gradient, determined by the negative constant b, is similar around all outbreaks.

The results are consistent with information on the movement of the mealybugs and spread of cacao swollen shoot virus in outbreaks. Moreover, they indicate that outbreaks are controlled most economically by removing all obviously infected trees and adjacent apparently healthy ones. Control does not require the destruction of all the trees around outbreaks up to a distance of thirty yards as done previously, but can be achieved by felling fewer trees, the actual number depending on the size of the outbreak.

—— and Tinsley, T. W. (1960): 'The virus complex causing Swollen Shoot disease of Cacao in West Africa'. F.A.O. *Pl. Prot. Bull.*, **8,** pp. 65–69.

—— —— (1960): 'The Viruses of Cacao'. *W. Afr. Cocoa Res. Inst. Tech. Bull.*, No. 7.

Turner, P. D. (1959): Report on a visit to the Southern Cameroons, Fernando Po and French Cameroons. (Cyclostyled.)

—— (1960a): 'A world survey of *Phytophthora palmivora* on cocoa'. *Plant Disease Reptr.*, **44,** p.221.

—— (1960b): 'Distribution of strains of *Phytophthora palmivora* from *Theobroma cacao* in West Africa'. F.A.O. *Plant Prot. Bull.*, **8,** pp. 53–54.

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—— and Turner, P. D. (1960): '*Phytophthora palmivora* causing a leaf and stem blight of cocoa'. *Commonwealth Phytopath. News*, **6,** p. 13.

BALANCE SHEET

AS AT 31st MARCH 1960

WEST AFRICAN COCOA

BALANCE SHEET AS

LIABILITIES

	£ s. d.	£ s. d.
Surplus Account		2,232,192 11 8
Sundry Creditors	8,527 17 8	
Provisions and Accrued Charges	15,753 14 5	
		24,281 12 1

(Sgd.) JAMES LAMB, *Director.*

(Sgd.) J. N. A. HYDE, *Accountant.*

£2,256,474 3 9

We have audited the above Balance Sheet of the West African Cocoa Researc and explanations that we have required. In our opinion and subject to our Report of eve position of the Institute as at 31st March 1960, according to the best of our information an

Accra,
4th August, 1960

ESEARCH INSTITUTE

T 31st MARCH 1960

ASSETS

	£ s. d.	£ s. d.
AND AND BUILDINGS—		
Cost to 31st March 1959	436,578 1 0	
Additions during the year	24,738 14 6	
	461,316 15 6	
Less Amount written off	461,316 15 6	
URNITURE AND EQUIPMENT—		
Cost to 31st March 1959	59,864 16 2	
Additions during the year	19,573 19 0	
	79,438 15 2	
Less Amount written off	79,438 15 2	
UNDRY DEBTORS—		
Staff Advances—Tafo 9,290 0 2		
—Ibadan .. 3,014 10 0		
	12,304 10 2	
Miscellaneous Debtors	1,884 8 8	
Deposits and Prepayments	5,589 9 7	
W.A.C.R.I. Club and School	26 8 5	
		19,804 16 10
TORES—At Cost—		
Timber	1,567 18 5	
Fuel	418 7 7	
Films	142 12 1	
Maintenance	11,761 8 11	
		13,890 7 0
NVESTMENTS—At Cost		2,004,322 10 7
(Market Value at 31.3.60, £1,643,276 9s. 6d.)		
ASH, BANK BALANCES AND FUNDS WITH CROWN AGENTS—		
Cash on Hand—Tafo	747 9 11	
—Ibadan	80 3 6	
Bank of West Africa Limited—		
Current Account—Tafo	21,758 17 9	
—Ibadan	2,699 18 0	
Savings Account	1,157 18 1	
Post Office Savings Bank	4,258 6 9	
Crown Agents—Joint Miscellaneous Fund ..	183,683 15 0	
—Endowment Fund	3,975 0 0	
—Current Account	95 0 4	
		218,456 9 4
		£2,256,474 3 9

tute with the books and vouchers of the Institute and have obtained all the information attached hereto, this Balance Sheet sets forth a true and correct view of the financial xplanations given to us and as shown by the Books of the Institute.

(Sgd.) CASSLETON ELLIOT & CO.
Auditors.

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